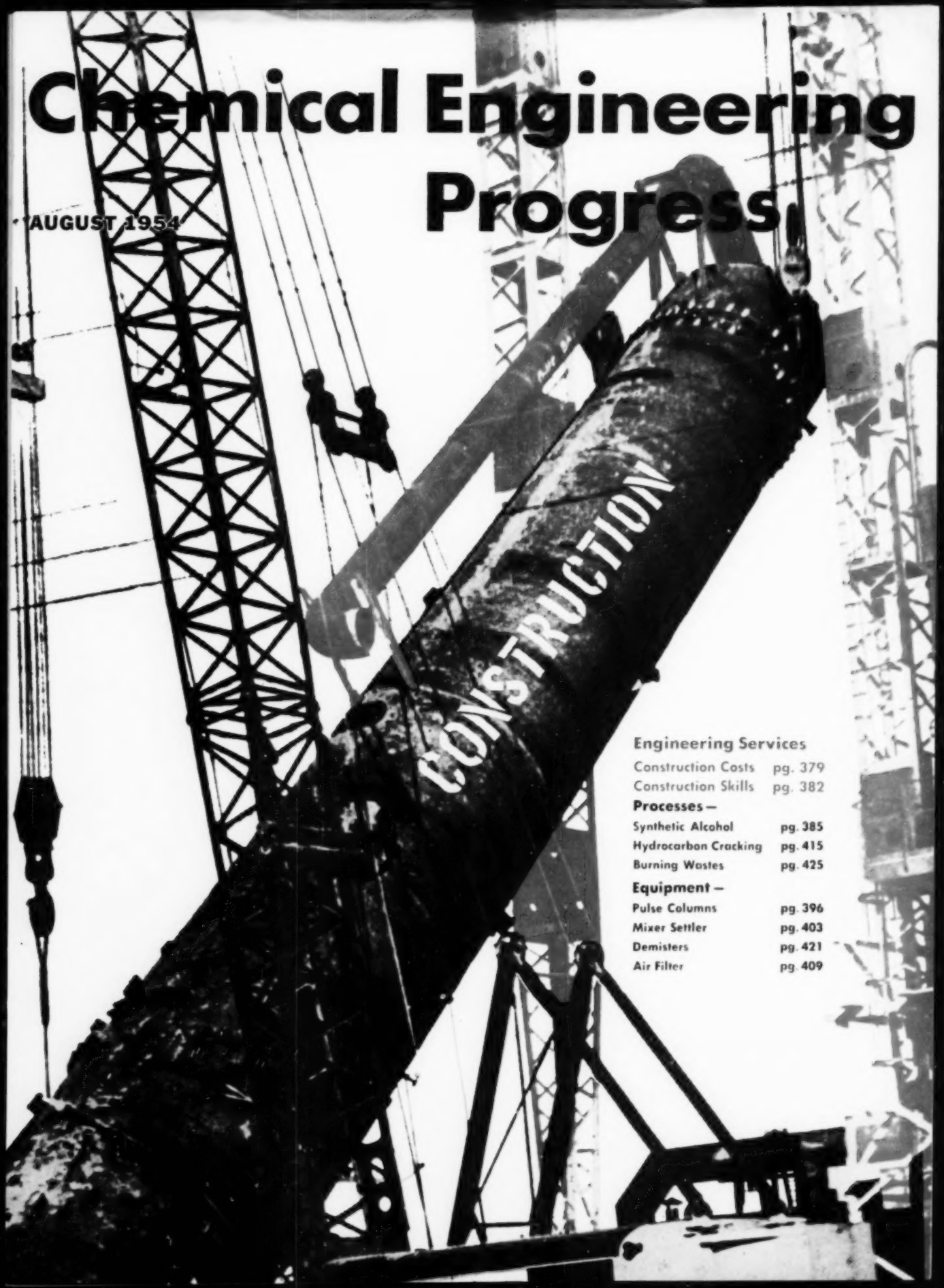
Chemical Engineering Progress

AUGUST 1954



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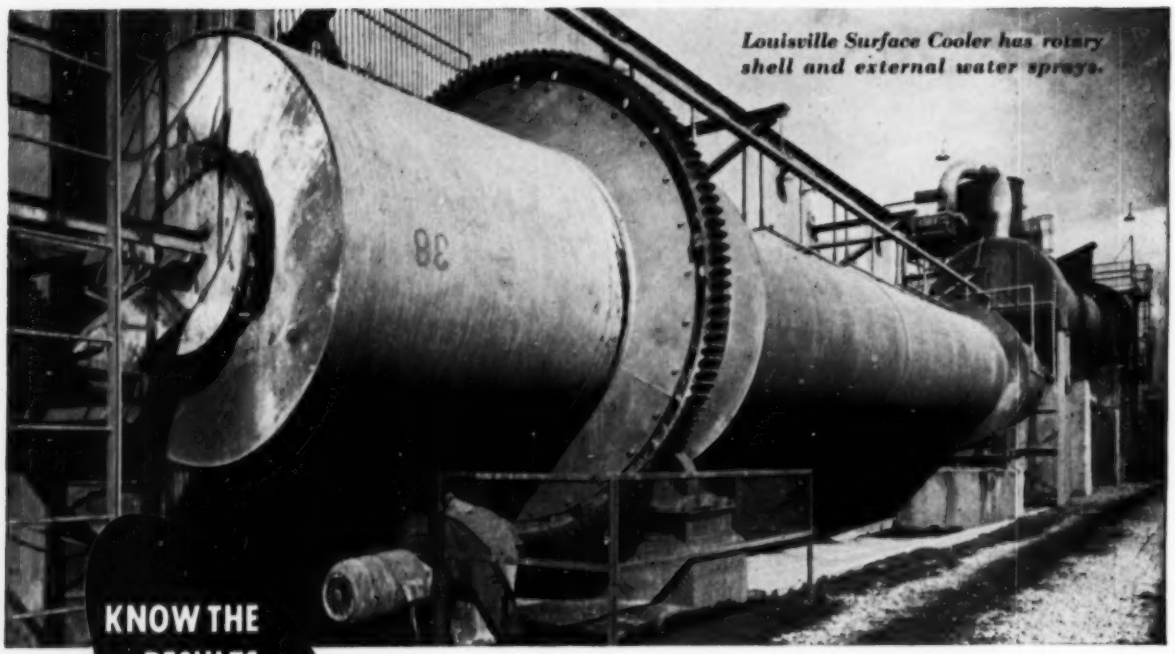
CREATIVE COOLING ENGINEERING

Louisville Cooler does satisfactory job at low cost for nationally known chemical manufacturer . . .



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Chemical Engineering Progress

AUGUST, 1954

Volume 50, No. 8

Editor: *F. J. Van Antwerpen*

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Advertising Manager: *L. T. Dupree*

THIS MONTH'S COVER

Construction as an important aspect of the chemical engineer's responsibility is depicted graphically in this month's cover design. Readers have probably noted the relationship between cover theme and a grouping of two or more articles on related aspects of the theme subject. This month chemical engineers are given the benefit of many years of experience by two outstanding authors from the vantage point of the construction contractor, and the process operator respectively.

Published monthly by American Institute of Chemical Engineers, at 15 North Seventh Street, Philadelphia 6, Pennsylvania, Editorial and Advertising Offices, 25 West 45th Street, New York 36, N. Y. Communications should be sent to the Editor. Statements and opinions in *Chemical Engineering Progress* are those of the contributors, and the American Institute of Chemical Engineers assumes no responsibility for them. Subscriptions: U. S. and possessions, one year $6.00; two years $10.00 (Applies to U. S. and possessions only.) Canada, $6.50; Pan American Union, $7.50; Other Foreign, $8.00. Single Copies of *Chemical Engineering Progress* older than one year cost $1.00 a copy; others are 75 cents. Entered as second class matter December 9, 1946, at the Post Office at Philadelphia, Pennsylvania, under Act of August 24, 1912.

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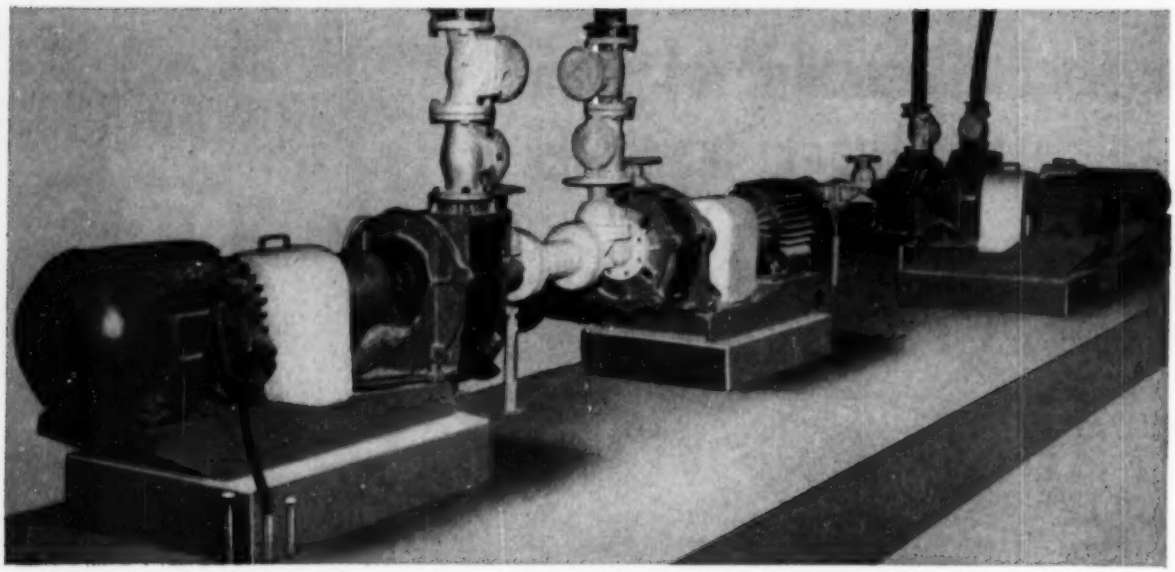

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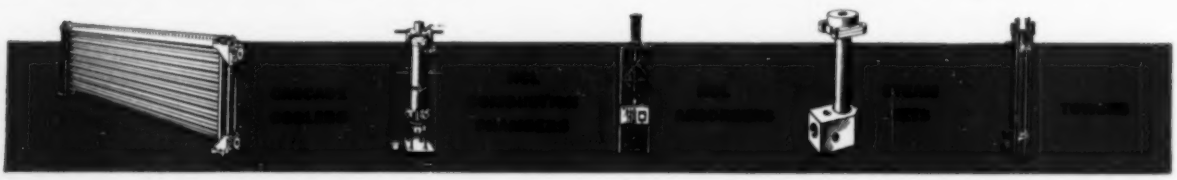

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. . . in these 16mm, full-color movies on "Karbate" impervious graphite equipment. Conveniently divided into "what is it" and "how to" sections – "MEETING THE CHALLENGE" and "BY WAY OF EXPERIENCE." History of the material, development, industrial applications . . . plus step-by-step installation and maintenance. WRITE – right now – for showing dates.

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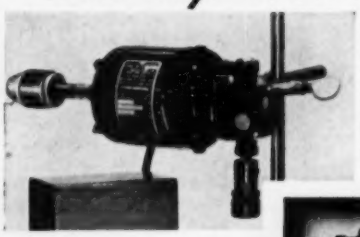
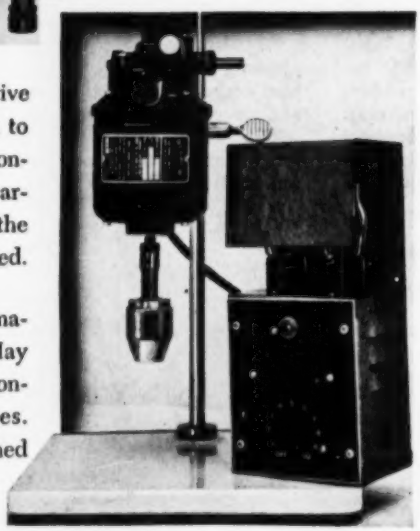


Direct and gear drive in one fully enclosed ball bearing motor. Variable Speed at full torque. 1/50 H.P. motor. Can be run in either direction.

The speed on direct drive ranges from 400 rpm to 5000 rpm in stepless control. The speed of gear-driven shaft is 1/18 the direct or armature speed.

Starting torque on armature is 32 in ounces. May also be used to drive constant speed devices. Stirrer can be attached to ordinary laboratory support stand.



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Motor is driven by a phase shift Thyratron Tube controlled rectifier, which converts the alternating current of the mains to direct current. Field and armature of motor are fed separately by two—2050 gas rectifier tubes. **Price $89.50**

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Newest of the new Laboratory Stirrers
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NOTED AND QUOTED

Isolation and Objectivity

If there is a "scientific mind," is self-isolation one of its necessities? Henry Cavendish, an aristocratic recluse after whom the Cavendish Laboratory of Cambridge University is named and one of the greatest chemists and physicists of the late eighteenth and early nineteenth centuries, talked only of science and even had his food passed to him by a servant who was not allowed to enter his room. Pavlov knew nothing of the events that led to the Russian Revolution nor of the revolution itself until an assistant excused himself for being late at the laboratory because the Bolsheviks had torn up streets and stopped street cars.

Josiah Willard Gibbs, the greatest scientist this country ever produced, lived and died in New Haven, an obscure professor who shut himself from the outer world in his later years. He was not moved by the issues of the Civil War, nor did he care whether his monumental work, "On the Equilibrium of Heterogeneous Substances," was translated into German or not. He never married, worked alone, and lived and died within a few hundred yards of the house in which he was born.

. . .

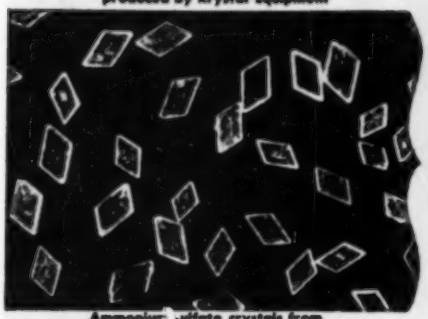
Though scientists disagree on what the "scientific method" is, they do agree that the essence of all scientific thinking is objectivity, which implies the complete separation of emotion, prejudice, even traditional belief from what is observed, tested or measured, and which is supposed to be possessed only by the "scientific mind." Thomas Huxley once said, "God give me strength to face a fact though it slay me." That is objectivity.

Only the greatest scientists have the strength for which Huxley prayed. Buffon, the naturalist, could not bring himself to believe that man was only a rather high animal. Needham was so set in his belief that life can be generated spontaneously that he fooled himself by failing to boil cultures of bacteria long enough to kill them. Only scientists who have the strength to tear away the trappings of conventional thinking make great names in science.

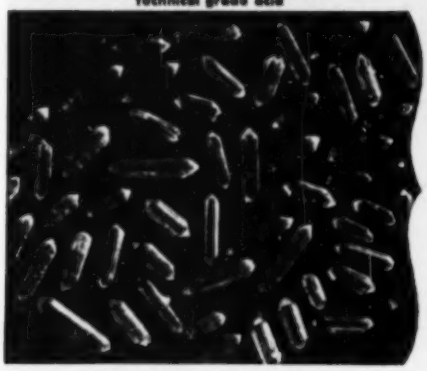
Objectivity, the gift of unflinchingly facing facts, is not a monopoly of scientists. Eminent lawyers, financiers, statesmen and generals have it. They are just as "scientific" for that reason as any physicist or chemist. Objectivity always goes with mental ruthlessness.

(*Continued on page* 8)

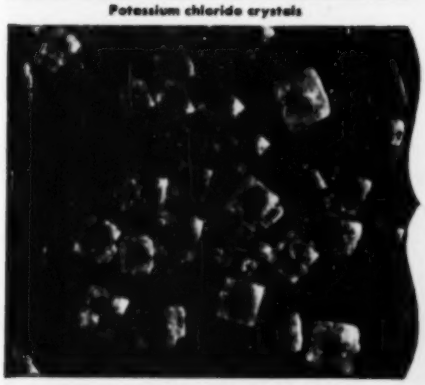
Potassium carbonate crystals produced by Krystal Equipment



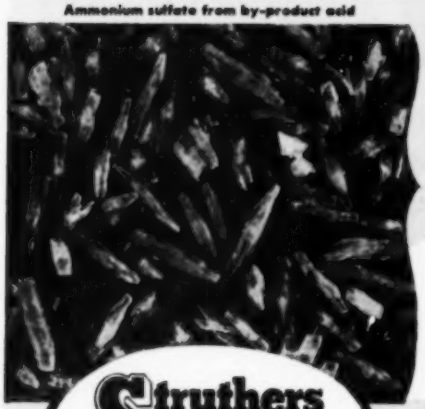
Ammonium sulfate crystals from technical grade acid



Potassium chloride crystals



Ammonium sulfate from by-product acid



Fluidized Crystal Suspension in

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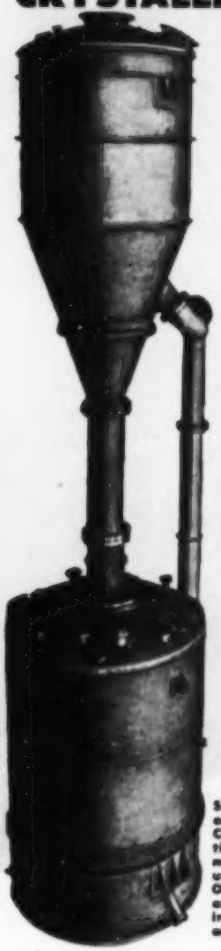

Shop view of Krystal Crystallization Equipment. This unit is 30' 0'' high and 11'3'' in base diameter.

Economical operation—Heating and cooling surfaces stay clean

Excellent steam economy

Product of high purity

Exceptionally uniform crystals

Controllable crystal size

Shown above is a typical installation of a Struthers Wells Krystal vacuum crystallizer.

Krystal crystallization equipment provides efficient separation of crystals and mother liquor—reduces amount of wash water—eliminates dust losses—reduces caking of material in storage and produces free flowing crystals of superior appearance.

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NOTED AND QUOTED

(*Continued from page 6*)

Great business men are ruthless in competition. They are also very "scientific" in the market studies that they direct so that ruthless decisions can be made.

If objectivity is as common among lawyers and business men as it is among scientists, curiosity is not. The creative scientist is forever wondering why things are as they are or why there are departures from the ordinary. Many a great scientific discovery is made because of this almost child-like inquisitiveness. . . .

Of all these attributes of scientific thinking objectivity is the most important. The late Alfred North Whitehead called it "the most important change in outlook that the human race has encountered."

Waldemar Kaempffert
New York Times

Nights Not Knights!

In a technological age the philosophy—which is basically political—that every man must serve in uniform is an anachronism that might have helped Custer in the battle of the Little Big Horn but which was a major factor in the utter rout of the French in 1940. For all our scientific progress, we seem to do our thinking in the framework of the historical-fictional world of James Fenimore Cooper, or of the Knights of the Round Table. Wits must now be matched in the laboratory, if only to save lives on the battlefield.

Howard A. Meyerhoff
Bulletin of the Atomic Scientists

An Ounce of Prevention . . .

. . . "The aim of all chemical procedure should be the utilization of everything and the avoidance of waste. It is often cheaper to prevent waste than to attempt to utilize a waste product."

George E. Davis
quoted by Norman Swindin

No World War II?

. . . Had airborne radar been developed and advertised openly, the consequent great progress in these developments might have so weakened the German confidence in their submarine supremacy, or in their capabilities for strategic air attack, that the war might have been prevented altogether.

L. V. Berkner, President
Associated Universities, Inc.
New York

(*More Noted and Quoted on page* 12)

NOW!

Lapp *Auto-Pneumatic* PULSAFEEDER

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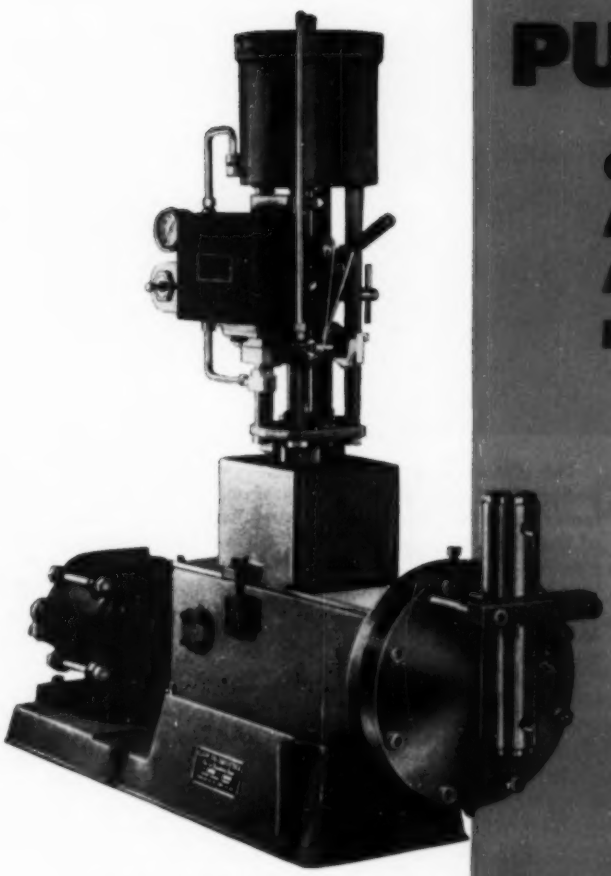
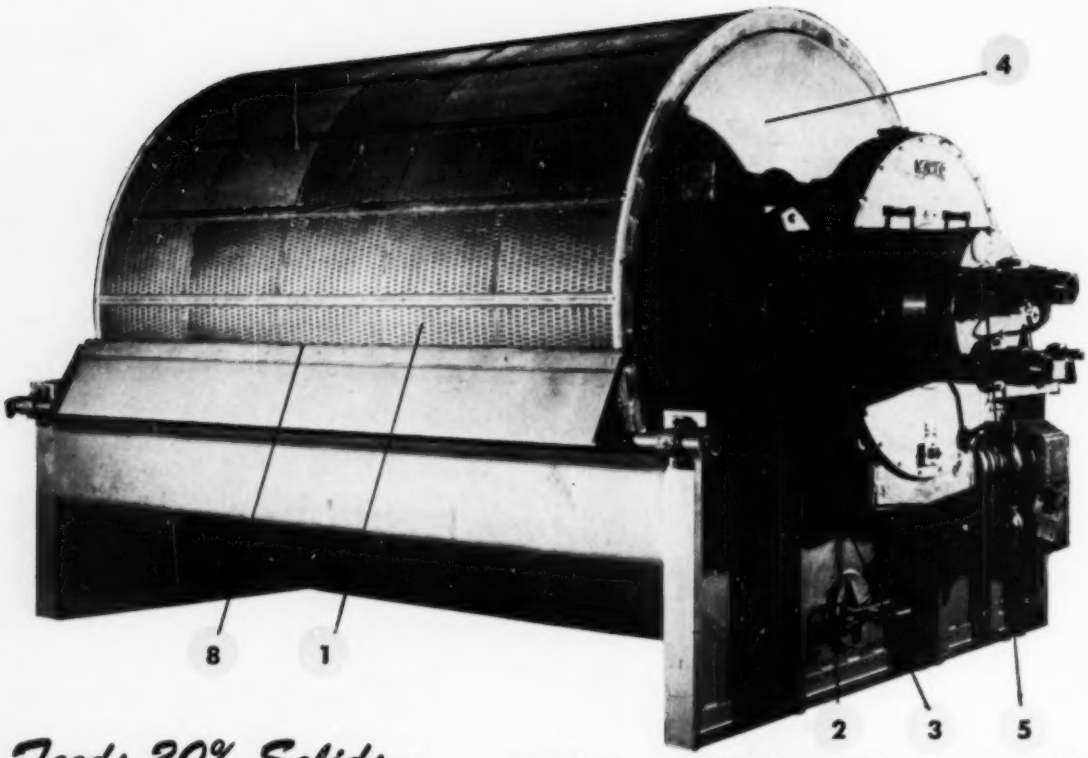
The Lapp Auto-Pneumatic Pulsafeeder has made possible automatic continuous processing in many processes involving chemicals or mixtures which have not been satisfactorily handled by pumps of conventional construction. In this construction, pumping rate is controlled by instrument air pressure responsive to variable flow, pH, temperature, liquid level, pressure, or any other instrument-measurable processing variable. And now, new improved Auto-Pneumatic instrumentation provides for greater capacity and/or pressure—full ratings as listed for manually-controlled models.



TWO PUMPS IN ONE!

Lapp Pulsafeeder is the combination piston-diaphragm pump for controlled-volume pumping of fluids. Reciprocating piston action provides positive displacement. But the piston pumps only an hydraulic medium, working against a diaphragm. A floating, balanced partition, the diaphragm isolates chemical being pumped from working pump parts—eliminates need for stuffing box or running seal. Constant pumping speed; variable flow results from variation in piston-stroke length —controlled by hand-wheel, or, in Auto-Pneumatic models, by instrument air pressure responding to any instrument-measurable processing variable.

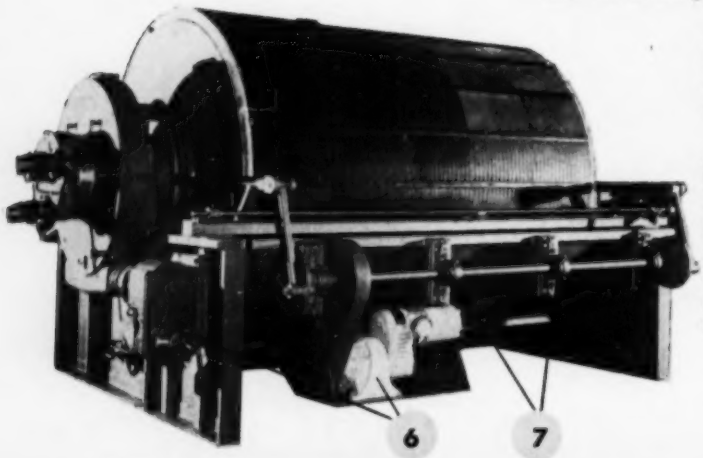
WRITE FOR BULLETIN 300 with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Div., 401 Wilson St., Le Roy, N.Y.



Feeds 20% Solids--

Cake 89% Solids

This filter, a standard drum continuous vacuum filter design with most advanced features adapted for the customer's problem, incorporates such items as (1) rubber grids of thermo plastic type, (2) easy access through quick opening tank covers, (3) counterweighted pin type agitators, (4) steel drum-heads mastic coated, snap blow, rubber base plastic piping, (5) marine bronze valve and wear plate, (6) variable speed drives on drum and agitator, (7) anti-friction bearings on agitator shaft.



In operation a dutch weave wire cloth is caulked in the grooves and the snap blow lifts the cake from the panel away from the drum surface so that the (8) rubber tipped blade never touches the drum.

All Eimco filters are engineered and designed with the idea of prolonging cover or bag life. Eimco engineers will consult with you in the selection of the correct media for best filtration and longest life and supply you with samples of Eimco media for your own laboratory work or will advise you on shipment of samples to Eimco Research Center for free filtration analysis.

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You Can't Beat An Eimco

CHEMICAL PROCESS NEWS

PUBLISHED BY CHEMICAL PROCESS DIVISION, THE M. W. KELLOGG COMPANY AUGUST 1954

NOTES ON SYNTHOL

Synthol is the name of the Kellogg-developed process for catalytically reacting synthesis gas (carbon monoxide and hydrogen) to produce a wide variety of hydrocarbon materials and chemicals. Synthesis gas for the process can be derived from either natural gas or coal.

• • •

The first plant to utilize Synthol on a commercial scale is now under construction by Kellogg in South Africa. Partial combustion of coal (from vast deposits near the plant site) will form the source of the synthesis gas; primary products of the plant will be "petroleum" fuels—around 60 million gallons per year, of which the major part will be motor gasoline.

• • •

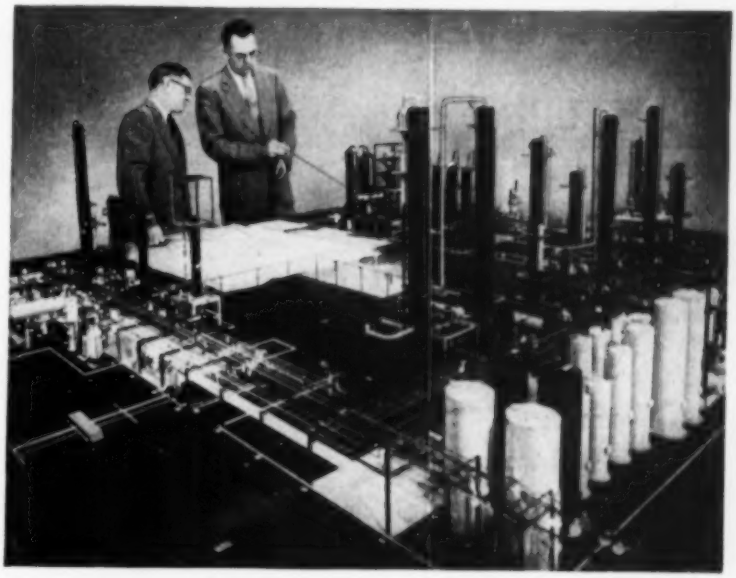
In addition to gasoline and fuel oil, the plant's output will include an impressive quantity of industrial and agricultural chemicals—about 125 million pounds. Many of these are oxygenated compounds, produced as by-products in the Synthol unit. While their volume is small in comparison with the enormous amounts of fuels produced, the higher market value of these chemicals adds substantially to the over-all attractiveness of the Synthol process.

• • •

The water-soluble or chemical stream from the Synthol unit is passed through a series of operations involving both extractive and conventional distillation to separate methanol, anhydrous ethanol, methyl ethyl ketone, and acetone. The methanol will be used as a solvent in the process and the ethanol will be blended into the gasoline pool. The other two chemicals will be marketed.

• • •

Additional equipment is being installed to produce commercial grade propanol and/or butanol, or to further process these products as additional gasoline.



Low Production Costs, High Yields and Flexible Operation Characterize New Phenol-from-Cumene Process

Shown above is a detailed model of a unique chemical plant Kellogg is currently building for Hercules Powder Company at Gibbstown, N.J. The plant will produce phenol, acetone, and methyl styrene, using the Hercules-Distillers process for oxidizing and splitting cumene. Kellogg, which developed the mechanical design of the commercial process in collaboration with Hercules, is also the originator of the process to be used for making the cumene feed.

The over-all process offers an unusual example of how refinery products can be upgraded to industrial chemicals to obtain a radical increase in value.

The phenol portion of the output is derived from the benzene part of the initial input. In the same way, the acetone produced is attributable to the low-cost propylene third of the feed.

As compared with other processes, the latter product—acetone—at present prices provides a bonus for the phenol produced as a major product. Moreover, the comparatively small quantity of methyl styrene produced can be separated for use in the plastics industry, or it can be converted back to cumene and re-used in the process.

For further information, technical data, etc., relating to chemical or petrochemical processing, write

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NOTED AND QUOTED

(*Continued on page 8*)

Statistics and More Statistics

. . . There is general agreement that the total number of engineers at the present time is approximately a half million, which is about 12 times the number of engineers we had in 1900 and about twice the number we had in 1940. . . . The number of scientists is generally considered to be somewhat less than half the number of engineers. This number has also approximately doubled since 1940. . . .

The population of the United States increased from 39.8 million in 1870 to 151.4 million in 1950, an increase of 280%. During the same period the number of professional, technical, and kindred workers increased from 0.4 million to 5.0 million, an increase of 1150%; and those employed in science and technology increased from 12 thousand to 1,019 thousand, an increase of 750%. From 1930 to 1953 the population increased 28%, the number of engineers 133%, and the number of scientists 335%.

Henry H. Armsby
A.S.E.E. Conference

Fundamental Research and The Engineer

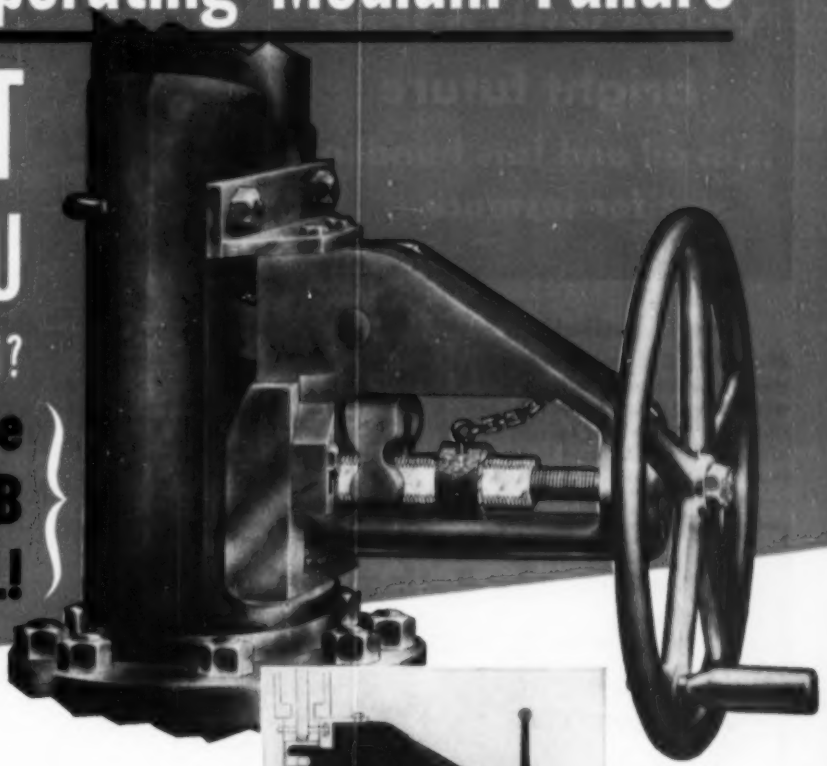
It is too often assumed that, since the job of the scientist is to do "basic" or "fundamental" research, therefore the job of the engineer is to avoid this and to invent gadgets. This is, of course, nonsense. The engineer *in a university* has just as much obligation to stick to the fundamentals in his field as the chemist or physicist in his. . . .

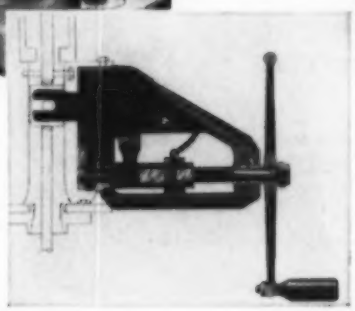
The university engineer is thus in an extremely critical position, intermediate between the pure scientist on the one hand and the industrial designer or inventor on the other. To some extent he does the things which the industrialist thinks the scientist ought to do—but which the scientist has lost interest in. The physicist is engrossed in the problems of nuclear forces; who is going to develop the fundamentals of nuclear technology? It's a long step from Fermi's first chain reaction to the first economical power plant—and lots of room in between for fundamental engineering research. The same is true in any field. Isn't this the proper place for university research in engineering?

L. A. DuBridge
A.S.E.E. Conference

Would an Operating Medium Failure SHUT YOU DOWN?

Not if you have this BS&B MANUAL CONTROL!





If the diaphragm control valves in your plant were suddenly rendered inoperative by failure of the operating medium, (or in rare instances by diaphragm failure within the valve), would you be forced to shut down immediately while repairs were made? Not if your valves are equipped with the BS&B Type Y Continuously Connected Side Handwheel for emergency manual control!

The Type Y is especially designed for use with all BS&B Diaphragm Control Valves, including Types 15 and 86, and the pressure balanced Type 73, where no by-pass is provided around the valve. It has a cast iron frame which fits onto the various Climax Valve Yokes. Working parts are of stainless steel, and it is equipped with an Ampcoloy jack screw, "Oilite" bearings and a large handwheel for ease of operation.

With the Type Y, control valves can be manually positioned in either direction independently of the normal controlling impulses. Its mechanism provides stops so that travel can be set to cover any portion of the complete valve stroke.

Avoid costly shut-downs due to operating medium or diaphragm failure! You can keep your plant operating indefinitely on an emergency basis if your control valves are equipped with the BS&B Type Y Continuously Connected Side Handwheel!

For complete information on any BS&B Climax Control or accessory, ask your BS&B Man, or write to . . .

CLIMAX BS&B CONTROLS OVER 60 YEARS

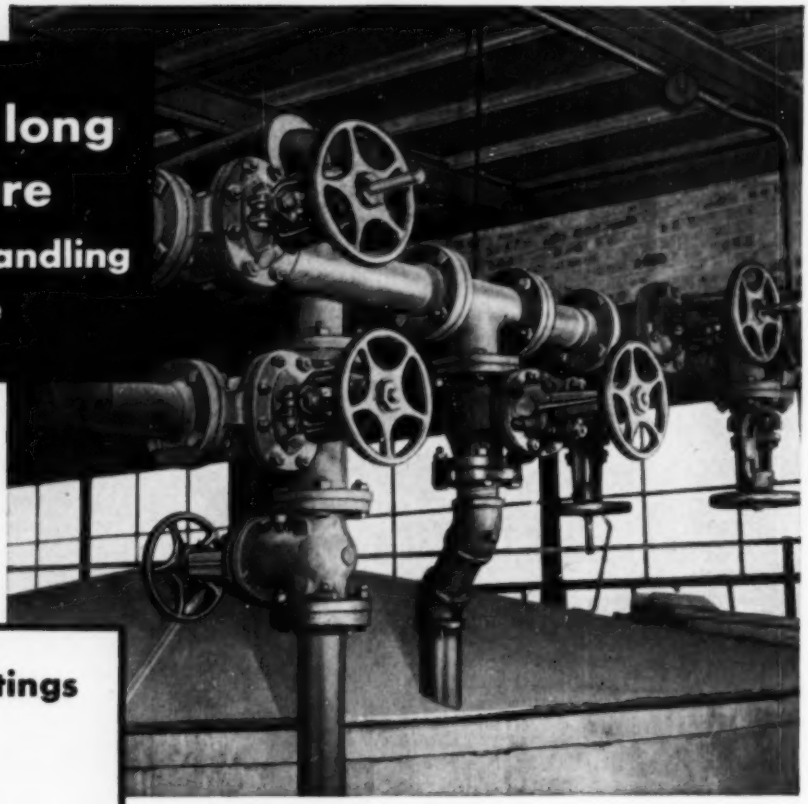
BLACK, SIVALLS & BRYSON, INC.

CLIMAX CONTROLS DIVISION, DEPT. 4-DX8

7500 East 12th Street Kansas City 26, Missouri

Valve with a long bright future

...in oil and fats handling for instance



The Installation

At Swift & Co. technical products plant in Hammond, Indiana, where hundreds of Crane valves are handling vegetable and animal fats, various fatty acids, acid foots, etc., in storage and preparation sections.

Valve Service Ratings

SUITABILITY:
Stopped former trouble

FEATURES:
Stainless Steel trim

MAINTENANCE COST:
Zero

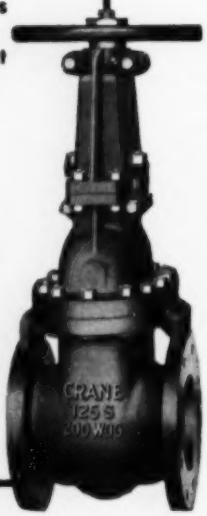
SERVICE LIFE:
No sign of wear after 3 years

OPERATING RESULTS:
Accurate control—clean plant

AVAILABILITY:
Crane Branches Everywhere

The Valve

It's the familiar, universally-used Crane 125-Pound OS&Y Iron Body Wedge Gate, but equipped with special Crane 18-8 SMo stainless steel trim to resist the mildly corrosive effects of fatty acids and acid foots. If you have a similar problem, this may be your solution. Ask your Crane Representative to help you.



The Case History

The plant had been operating about two years when the Crane valves were installed. They were selected to replace the plant's original valves which were not maintaining the required absolute tightness when process pipe lines were shut off.

The Crane valves, now in service for more than three years, are iron body gates with stainless steel trim. Recently the plant reported: no leakage . . . no maintenance . . . no replacements. Also credited to the Crane valves: more accurate control of processes . . . and a much cleaner plant.

THE BETTER QUALITY... BIGGER VALUE LINE... IN BRASS, STEEL, IRON

CRANE VALVES

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING

to fully effective heat input in minutes—

that's the story of the...

Blaw-Knox radiant furnace

The Blaw-Knox Radiant Furnace for batch operation has such low heat capacity that it can be brought to fully effective operation in five minutes or less. Cut the fuel supply and it is black in one to two minutes.

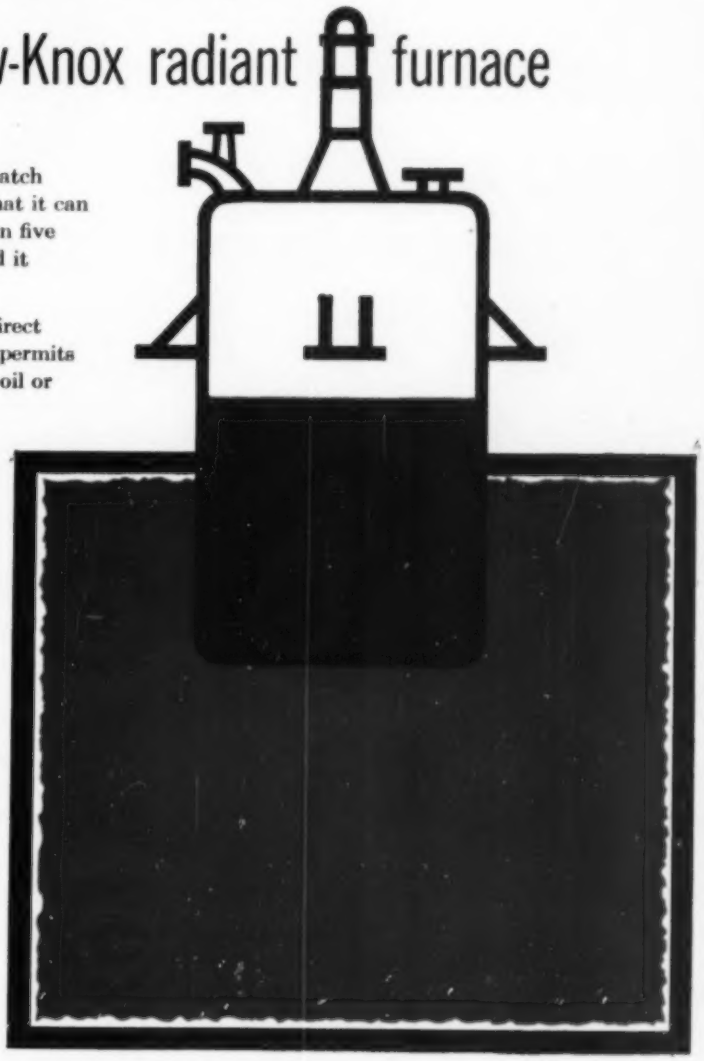
The nearly instantaneous response to direct instrument regulation of the fuel input permits close temperature control of a batch of oil or resin, even in an exothermic stage. Successive cooking curves on different days are smooth and identical.

The basic design of the Blaw-Knox Radiant Furnace is a light stainless steel shell surrounded by high temperature, light weight insulating material.

Approximately 75 percent of the heat to the batch is supplied by radiation from furnace walls arranged to eliminate local hot spots.

Field reports of normal plant operation indicate fuel savings close to 50 percent over conventional, brick-lined, direct-fired furnaces.

Write for complete information on the application of this low heat capacity furnace to direct-fired processes.

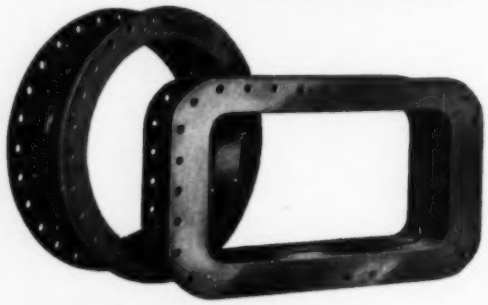


BLAW-KNOX COMPANY Chemical Plants Division /Pittsburgh 22, Pennsylvania
Tulsa 1, Oklahoma /Chicago 1, Illinois

Garlock Rubber Expansion Joint on vacuum line between turbine and condenser.

Expansion joints in operation on 2½" suction and discharge pipes.

Expansion joint operating on suction side of centrifugal pump handling condensate from condenser.



GARLOCK RUBBER EXPANSION JOINTS

- Stop Vibration, Eliminate Noise
- Relieve Stresses and Strains in Piping and Equipment

Sectional view showing sturdy construction of a Garlock single arch spool-type expansion joint. Arrow points to one of steel reinforcing rings.

Garlock rubber expansion joints absorb vibration and compensate for linear expansion and contraction of pipe lines. They stand up under repeated flexing—do not crack or fracture.

These flexible joints are made in all pipe sizes from ¾" to 72". Furnished in round, rectangular, tapered or offset; spool-type and U-type. Garlock expansion joints are available in neoprene for oil service; in all "Teflon" or rubber with "Teflon" liner for chemical service.

Write today for new Rubber Expansion Joint Folder No. AD-137.

THE GARLOCK PACKING COMPANY, PALMYRA, NEW YORK

Sales Offices and Warehouses: Baltimore • Birmingham • Boston • Buffalo • Chicago Cincinnati • Cleveland • Denver • Detroit • Houston • Los Angeles • New Orleans • New York City • Palmyra, (N.Y.) • Philadelphia • Pittsburgh • Portland (Ore.) • Salt Lake City • San Francisco • St. Louis • Seattle • Spokane • Tulsa.

In Canada: The Garlock Packing Company of Canada Ltd., Toronto, Ont.

GARLOCK

PACKINGS, GASKETS, OIL SEALS
MECHANICAL SEALS
RUBBER EXPANSION JOINTS

Get in on the ground floor!

The circles on the map represent unclaimed territories for the production of complex fertilizer. The pin locates the only plant presently producing complex fertilizer by a continuous chemical process.

New economic frontiers don't remain undeveloped for long. There is still time to get a choice location before the rapidly moving trend toward high analysis complex fertilizer *completely engulfs the country.*

Get C&I's complex fertilizer plant using the PEC* patented carbonitric process that produces a superior and stable pelleted product for less than any existing process.

C&I will provide a complete and integrated plant or any of the individual units (ammonia, nitric acid, complex fertilizer) for the production of complex fertilizer in any desired capacity. Plants are erected at a fixed price with productions and efficiencies fully guaranteed.

C&I can also furnish the latest type ammonium nitrate solutions and solids plants.

C & I can now license Commercial Solvents' Stengel Reactor and furnish and erect the complete ammonium nitrate plant using the *new* Stengel Process.

*Procédé d'Engrais Chimiques

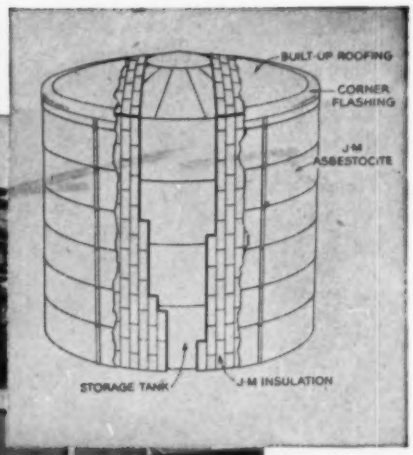
PEC

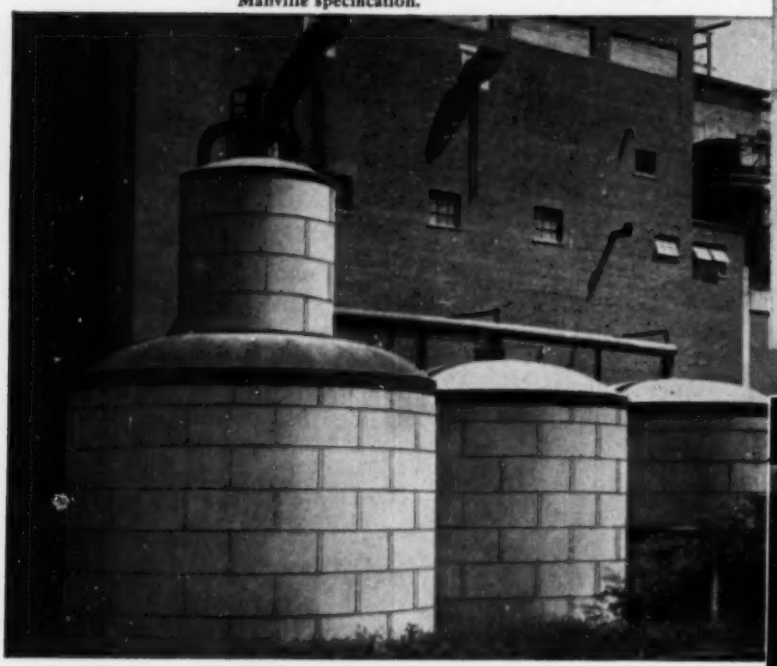
Specialists in C&I *Processing Ammonia*

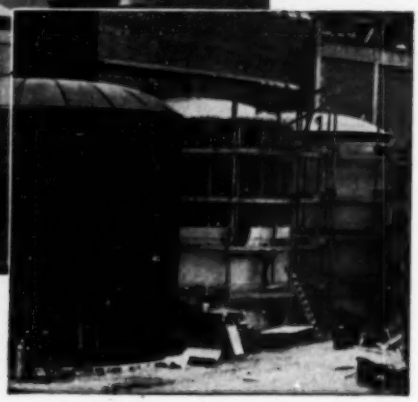
THE CHEMICAL & INDUSTRIAL CORP.

CINCINNATI 26, OHIO

Cutaway drawing shows how J-M *Weather-Protected* Insulation is applied to tanks such as those at the S. D. Warren Company paper mill. Standard methods for mechanical securement of the insulation are used. Asbestocite sheets are then applied over the insulation, in accordance with the simplified Johns-Manville specification.







▲ (Above) Completed job of J-M *Weather-Protected* Insulation on black liquor tanks of the S. D. Warren Company.

(Right) Skilled applicators of an outstanding J-M Insulation Contractor, P. S. Thorsen Co. of South Boston, Mass., applying Asbestocite sheets over Zerolite insulation.

S. D. Warren Company saves fuel, reduces maintenance on outdoor tanks with J-M *Weather-Protected* Insulation

On black liquor tanks of the S. D. Warren Company paper mill at Cumberland Mills, Maine, Johns-Manville *Weather-Protected* Insulation pays a "double dividend":

It saves money on fuel and maintenance. J-M Zerolite* insulation keeps the heat in . . . thereby saving a substantial amount in fuel costs. J-M Asbestocite*, a strong asbestos-cement sheet material, covers the Zerolite Insulation to protect it both from the weather and from wetting due to normal plant operations. This "bodyguard" layer of Asbestocite Weather Protection makes the tanks virtually maintenance-free and helps hold down operating costs.

It helps provide close temperature control. The temperature of black liquor in these tanks must be maintained so that it will flow freely and not clog up pumping apparatus. J-M Weather-Protected Insulation helps do the job dependably and economically.

Whatever the operating temperature of outdoor tanks and vessels, Johns-Manville offers the right insulation for application under the Asbestocite weather protection. For example, J-M 85% Magnesia Insulation is also widely used for this service because of its proved performance for temperatures to 600 F.

To be sure that the insulation and its weather protection is properly applied to pay the greatest return on your investment, J-M offers the services of experienced J-M Insulation Engineers and J-M Insulation Contractors. These men stand ready to give you an insulation job that will more than pay off your initial investment through maximum fuel savings.

For further information about J-M Weather-Protected Insulation, write to Johns-Manville, Box 60, New York 16, New York. In Canada, 199 Bay Street, Toronto 1, Ontario. *Reg. U.S. Pat. Off.

Johns-Manville *FIRST IN* INSULATION

MATERIALS • ENGINEERING • APPLICATION

THIS IS GIRDLER

This vinyl chloride monomer plant of B. F. Goodrich Chemical Company at Calvert City, Kentucky was built by Girdler. Plant in circle is hydrogen plant of Girdler design . . . also built by Girdler.

Another Chemical Plant built by Girdler

HERE IS FURTHER EVIDENCE of continuing confidence placed in Girdler service. This is the fifth major project to be completed for B. F. Goodrich Chemical Company by Girdler. Starting with Goodrich's basic process data, Girdler engineered and built this vinyl chloride monomer plant. Included is a hydrogen plant of Girdler design and construction. Efficient *coordination* of all project phases and *centralized responsibility* by Girdler saves valuable time. If you are planning an expansion or new facility, call Girdler . . . and profit from this *complete service.*

GIRDLER DESIGNS processes and plants

GIRDLER BUILDS processing plants

GIRDLER MANUFACTURES processing apparatus

GAS PROCESSES DIVISION:

Chemical Processing Plants — Plastics Materials Plants
Hydrogen Production Plants — Sulphur Plants
Hydrogen Cyanide Plants — Acetylene Plants
Synthesis Gas Plants — Ammonia Plants
Carbon Dioxide Plants — Ammonium Nitrate Plants
Gas Purification Plants — Hydrogen Chloride Plants
Catalysts and Activated Carbon

VOTATOR DIVISION: COMPLETE EDIBLE OIL PLANTS
CONTINUOUS PROCESSING APPARATUS FOR . . .

Chemicals	Resins	Lard
Textile Size	Strained Food	Shortening
Shaving Cream	Salad Dressing	Bakery Ingredients
Lubricating Grease	Soup	Confectioneries
Paraffin Wax	Margarine	Citrus Concentrates
Paper Coating	And other Products	

THERMEX DIVISION: HIGH FREQUENCY DIELECTRIC HEATING EQUIPMENT APPLIED TO . . .

Foundry Core Baking — Rubber Drying and Curing
Wood Bonding — Plastic Preform Preheating

The GIRDLER Company
A DIVISION OF NATIONAL CYLINDER GAS COMPANY
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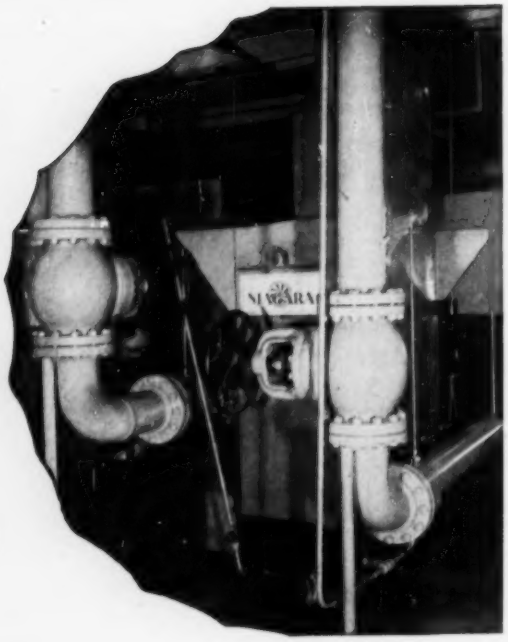
GAS PROCESSES DIVISION: New York, Tulsa, San Francisco
In Canada: Girdler Corporation of Canada Limited, Toronto
VOTATOR DIVISION: New York, Atlanta, Chicago, San Francisco

How to get drier or cooler air or gases . . .



NIAGARA AERO AFTER COOLER cools a compressed gas, or air, below the temperature of the surrounding atmosphere, thus preventing the condensation of moisture in your lines. The gas will contain only half of the moisture left in it by conventional methods. Even drier gas can be produced if you require it.

In working with controlled atmospheres of inert gases to prevent undesired reactions, this dryness of the gas at low cost is a great advantage. The cost of the Niagara method is low because it uses evaporative cooling, saving 95% of the cost of cooling water (and its piping and pumping). This direct saving of cost pays for the Niagara cooler in less than two years.

If you use compressed air to operate tools or pneumatic equipment you save much in water and oil damage to tools and equipment, and in water damage to materials by using the Niagara Aero After Cooler.

Write for a bulletin, or ask nearest Niagara Field Engineer if you have a problem involving the industrial use of air.

NIAGARA BLOWER COMPANY

Over 35 Years' Service in Industrial Air Engineering

Dept. EP, 405 Lexington Ave. **New York 17, N. Y.**

Experienced Field Engineers in Principal Cities of U. S. and Canada

MARGINAL NOTES

Reactors and Realism

A Forum Report on Nuclear Reactor Development. Proceedings of Meeting for Members and Guests. Oliver Townsend and Edwin Wiggin (Eds.). Atomic Industrial Forum, Inc., New York (1954), 99 pp. $5.00.

This report covers the proceedings of a meeting held under the auspices of Atomic Industrial Forum, Inc., on May 24, 1954, at the Sheraton Park Hotel, Washington, D. C., during which the top men in reactor development covered the A.E.C.'s five-year reactor program as well as private industrial development in the field. The speakers gave up-to-the-minute summaries on major programs now underway, outlined their plans for the future, and answered pertinent questions from the floor. Realistic public policy in atomic energy concluded the talks.

The report is available at $5.00 a copy from the Atomic Industrial Forum, Inc., 260 Madison Avenue, New York 16, N. Y.

A Practical Guide for the Practical Man

Flow and Fan. C. Harold Berry. The Industrial Press, New York (1954), 226 pp. $4.00.

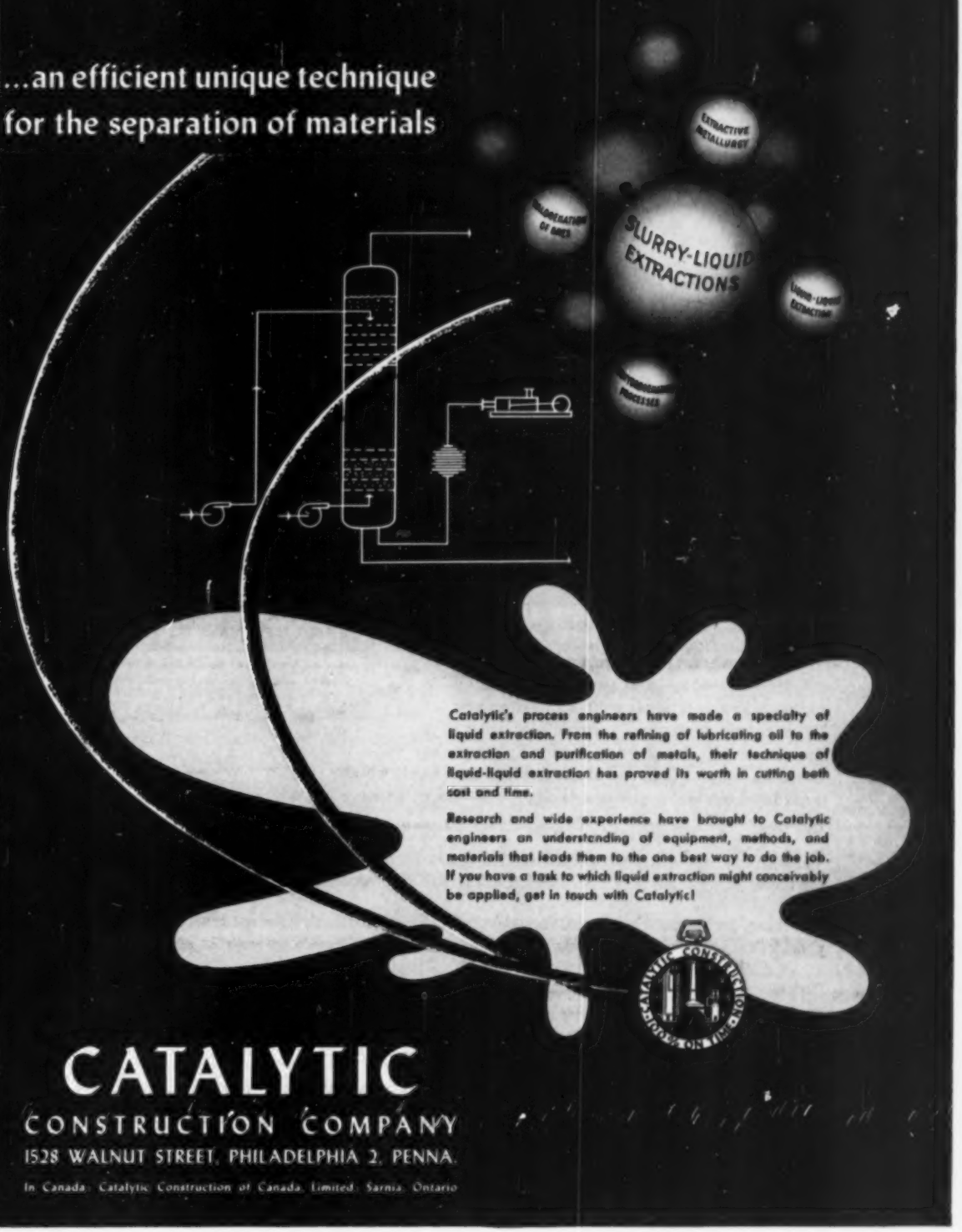
Reviewed by J. M. DallaValle, Professor, School of Chemical Engineering, Georgia Institute of Technology, Atlanta, Ga.

If a book is written to describe a piece of equipment, it should as a matter of course also indicate how the equipment should be used. Any number of books have been written about fans and pumps which stress design and operating principles, but leave the conditions for their use pretty much to the imagination. All this may be well for specialists, but there are many engineers who only occasionally have thrust upon them the job of laying out a duct system and selecting a prime mover and who, therefore, want readable and useful information. Professor Berry seems to be aware of this and has written a simple book which should furnish engineers about all they need to know on fans and ductwork.

This is not a profound work, but such it was never intended to be. Rather is it a book full of pertinent and practical information, stressing particularly the

(Continued on page 24)

...an efficient unique technique
for the separation of materials



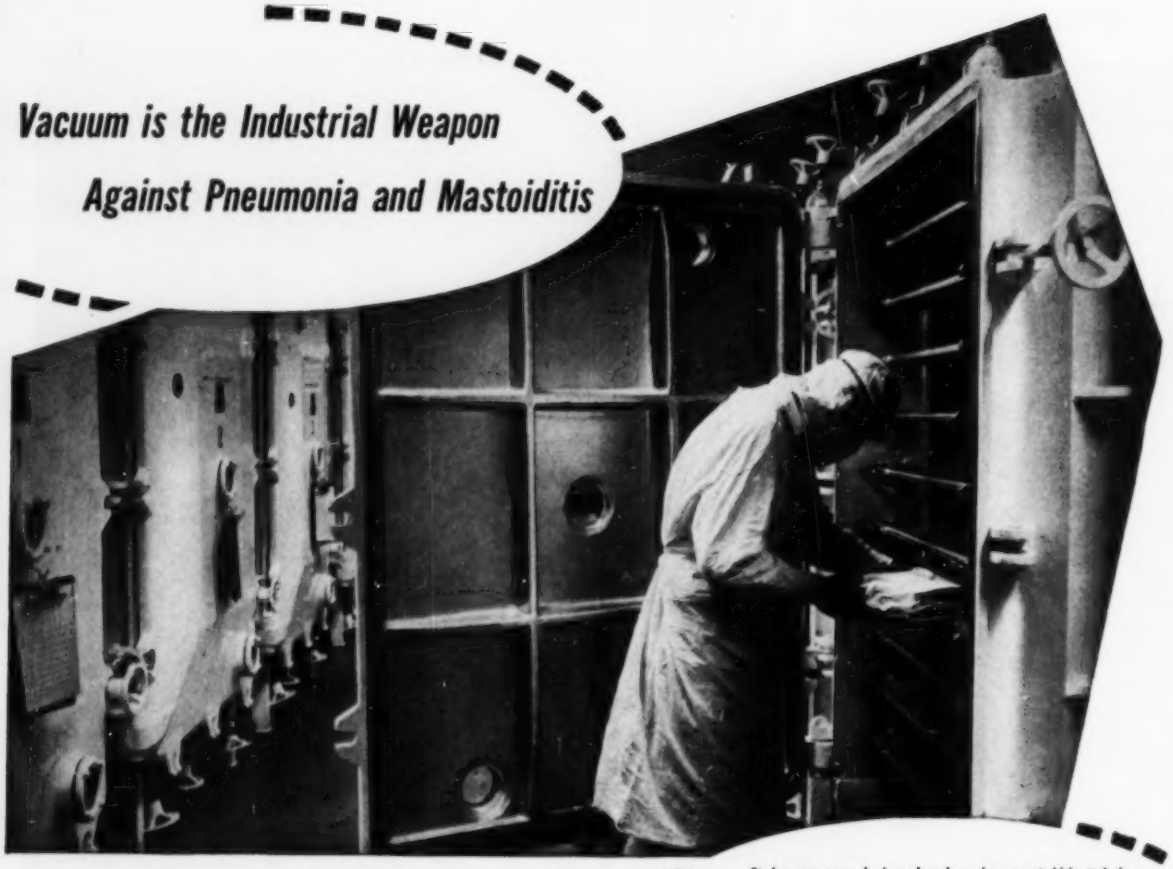
Catalytic's process engineers have made a specialty of liquid extraction. From the refining of lubricating oil to the extraction and purification of metals, their technique of liquid-liquid extraction has proved its worth in cutting both cost and time.

Research and wide experience have brought to Catalytic engineers an understanding of equipment, methods, and materials that leads them to the one best way to do the job. If you have a task to which liquid extraction might conceivably be applied, get in touch with Catalytic!

CATALYTIC
CONSTRUCTION COMPANY
1528 WALNUT STREET, PHILADELPHIA 2, PENNA.
In Canada: Catalytic Construction of Canada, Limited, Sarnia, Ontario

CATALYTIC *ON-TIME... ON-BUDGET* SERVICES for the atomic energy, chemical, petrochemical and oil refining industries
Process Design Project Analysis Economic Studies Engineering Procurement Construction Plant Operation

Vacuum is the Industrial Weapon Against Pneumonia and Mastoiditis



Stokes vacuum drying chambers in use at Abbott Laboratories, North Chicago, Ill., for the drying of crystalline penicillin and other antibiotics. Picture is taken through window of sterile drying room. Operator is masked and gloved to maintain sterile conditions.

Remember when these were dreaded afflictions? Now mastoid troubles are a rarity and pneumonia is no longer a dreaded killer, thanks to penicillin. Penicillin, dried in Stokes vacuum chambers at Abbott Laboratories, North Chicago, Ill., is one of many pharmaceuticals which must be dried under vacuum because only under vacuum are the destructive effects of air and heat avoided.

Vacuum drying — in many cases from the frozen state — is also the drying method for blood plasma, mycins, hormones, antibiotics, anti-venoms and biologicals.

For many industrial chemicals, vacuum drying is the efficient, low-cost high production method for removing water and recovering valuable solvents safely.

Stokes experts have 50 years of experience in vacuum processing to share with interested manufacturers. Send for any or all of the following informative brochures:

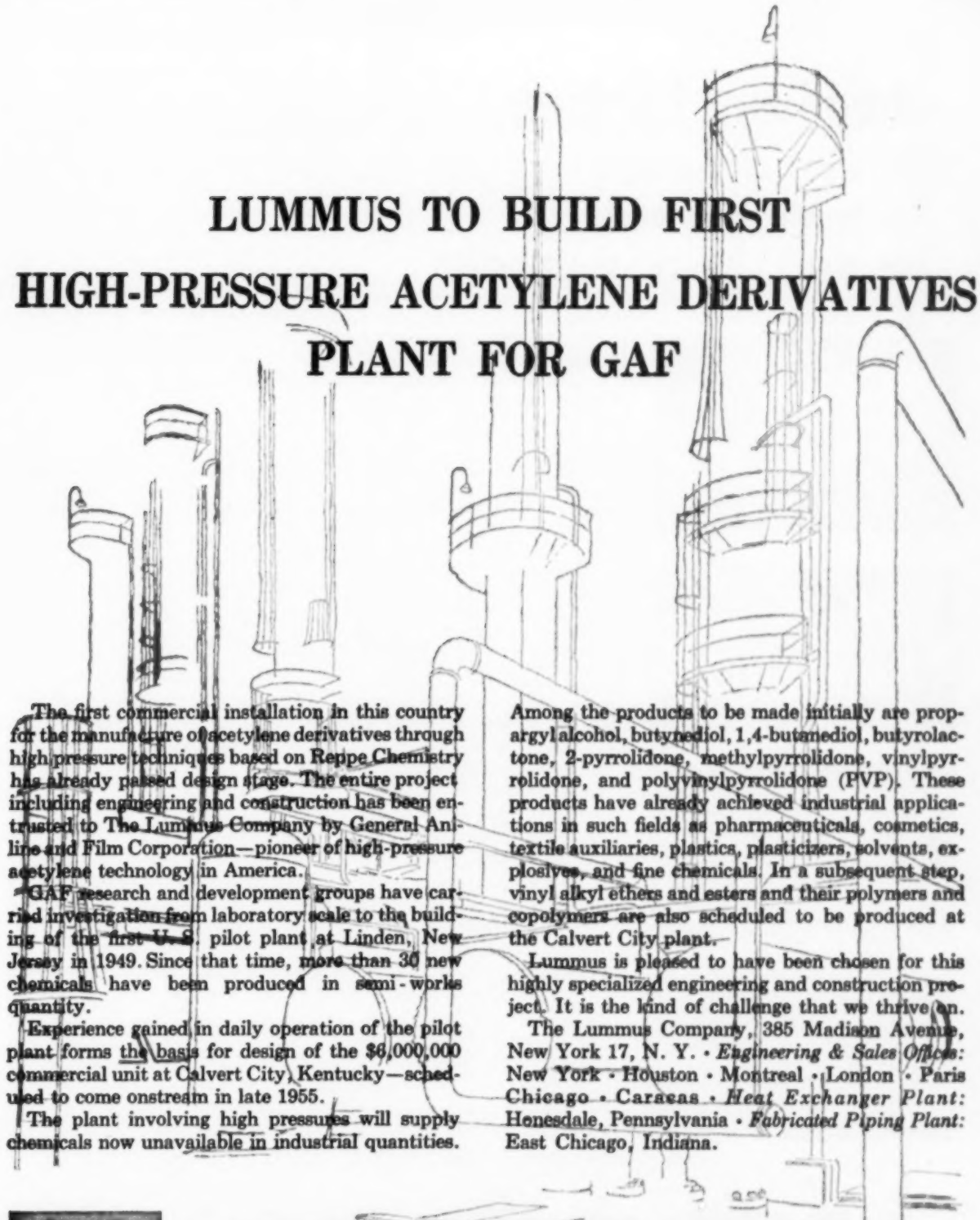
(1) Freeze-Drying in Industry,
(2) Laboratory Freeze-Drying,
(3) Vacuum Drying.

F. J. STOKES MACHINE COMPANY
PHILADELPHIA 20, PA.

STOKES

STOKES MAKES: High Vacuum Equipment, Vacuum Pumps and Gages / Industrial Tabletting, Powder Metal and Plastics Molding Presses / Pharmaceutical Equipment

LUMMUS TO BUILD FIRST HIGH-PRESSURE ACETYLENE DERIVATIVES PLANT FOR GAF



The first commercial installation in this country for the manufacture of acetylene derivatives through high pressure techniques based on Reppe Chemistry has already passed design stage. The entire project including engineering and construction has been entrusted to The Lummus Company by General Aniline and Film Corporation—pioneer of high-pressure acetylene technology in America.

GAF research and development groups have carried investigation from laboratory scale to the building of the first U. S. pilot plant at Linden, New Jersey in 1949. Since that time, more than 30 new chemicals have been produced in semi-works quantity.

Experience gained in daily operation of the pilot plant forms the basis for design of the $6,000,000 commercial unit at Calvert City, Kentucky—scheduled to come onstream in late 1955.

The plant involving high pressures will supply chemicals now unavailable in industrial quantities. Among the products to be made initially are propargyl alcohol, butynediol, 1,4-butanediol, butyrolactone, 2-pyrrolidone, methylpyrrolidone, vinylpyrrolidone, and polyvinylpyrrolidone (PVP). These products have already achieved industrial applications in such fields as pharmaceuticals, cosmetics, textile auxiliaries, plastics, plasticizers, solvents, explosives, and fine chemicals. In a subsequent step, vinyl alkyl ethers and esters and their polymers and copolymers are also scheduled to be produced at the Calvert City plant.

Lummus is pleased to have been chosen for this highly specialized engineering and construction project. It is the kind of challenge that we thrive on.

The Lummus Company, 385 Madison Avenue, New York 17, N. Y. • *Engineering & Sales Offices:* New York • Houston • Montreal • London • Paris Chicago • Caracas • *Heat Exchanger Plant:* Honesdale, Pennsylvania • *Fabricated Piping Plant:* East Chicago, Indiana.

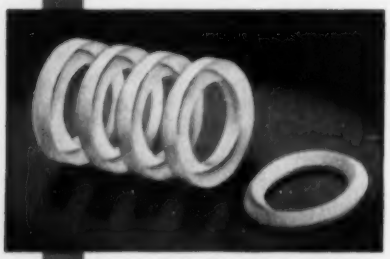
LUMMUS

DESIGNING ENGINEERS AND CONSTRUCTORS FOR THE PETROLEUM AND CHEMICAL INDUSTRIES

MADE OF TEFLON
(DuPont Trademark)

Chemiseal Packing

- won't contaminate
- won't deteriorate
- won't "freeze" shaft action

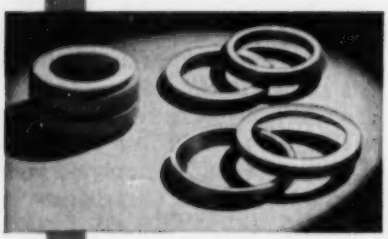


V-TYPE PACKING

Chemiseal Type 810 TEFLON V-Packing for use in manual, air or motor operated valves. Construction and distinctive tapered V design offers chemically impervious service and greater flexibility and resiliency, providing necessary seal at low gland pressure and reduced torque on valve stem.

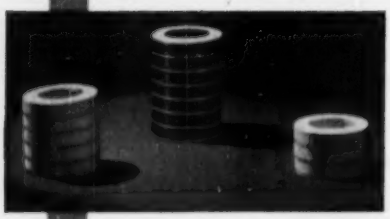
CUP AND CONE TYPE PACKING

Chemiseal Type 810-W TEFLON Packing for both hand and mechanically operated valves. Cones deform inwardly to effect a seal at the spindle, while cups expand outwardly against stuffing box wall, making possible a tight seal at low gland pressure.



WEDGE TYPE PACKING

Chemical Type 810-WX Packing offers the unusually low gland load required for valves made of Haveg, Karbate, ceramics, etc. Rings provide space for thermal expansion. Also adaptable for spring loading wherever exceptionally low friction load is required.



PUMP PACKING

Order Chemiseal Types 711-G, (graphite, impregnated) No. 711-M, (impregnated with mica) and No. 711-O (pure TEFLON). For general purpose or non-contaminating pump service throughout the processing industries.

▶ *Write for Catalog Number TP-1053.*

UNITED STATES GASKET COMPANY

CAMDEN 1 • NEW JERSEY

FABRICATORS OF duPont TEFLON, Kellogg KEL-F AND OTHER PLASTICS

Representatives in Principal Cities Throughout the World

MARGINAL NOTES

(*Continued from page 20*)

relation of the fan to the system it is connected with —a matter of considerable importance, often overlooked in many texts. There are three chief criticisms of the book from the standpoint of the chemical engineer. These are (1) It is limited to the movement of air only, (2) fan and duct requirements at high temperatures are not considered, and (3) fan and duct construction materials to resist corrosion are nowhere mentioned. These are regrettable omissions in an otherwise excellent and readable textbook.

A Bouquet to A.S.A.

Industrial Specifications. E. H. MacNiece. John Wiley & Sons, Inc., New York (1953), 158 pp. $4.50.

Reviewed by D. O. Myatt, Manager of Development, Atlantic Research Corp., Alexandria, Va.

Certainly the industrial specification is a critically important class of business and commercial communication, a place where precision saves dollars and headaches. For those whose jobs bring them in touch with specifications, Mr. MacNiece's slim volume will deserve examination. His explanation of the basic function of the good specification, namely to specify rather than generalize, and his discussions of tolerances and variability have the ring of expert experience. In this reviewer's opinion, the chapter on variability and tolerance is the high spot of the book.

Most of the book is descriptive rather than analytical. This reviewer believes that more emphasis in the text on working techniques, more attention to the organization of subject matter, an index to aid the reference functions, and some tables listing sources of established specifications and pertinent American Standards Association literature would have made the book more useful. The author tosses a well-deserved bouquet to the American Standards Association for the constructive part it has played in the standards and specifications field.

Chemical specifications are not particularly stressed. However, one or two specimen specifications, presented to illustrate the author's discussions, show how analytical tests and other criteria may be spelled out to eliminate ambiguity from such specifications.

(*More Marginal Notes on page 28*)

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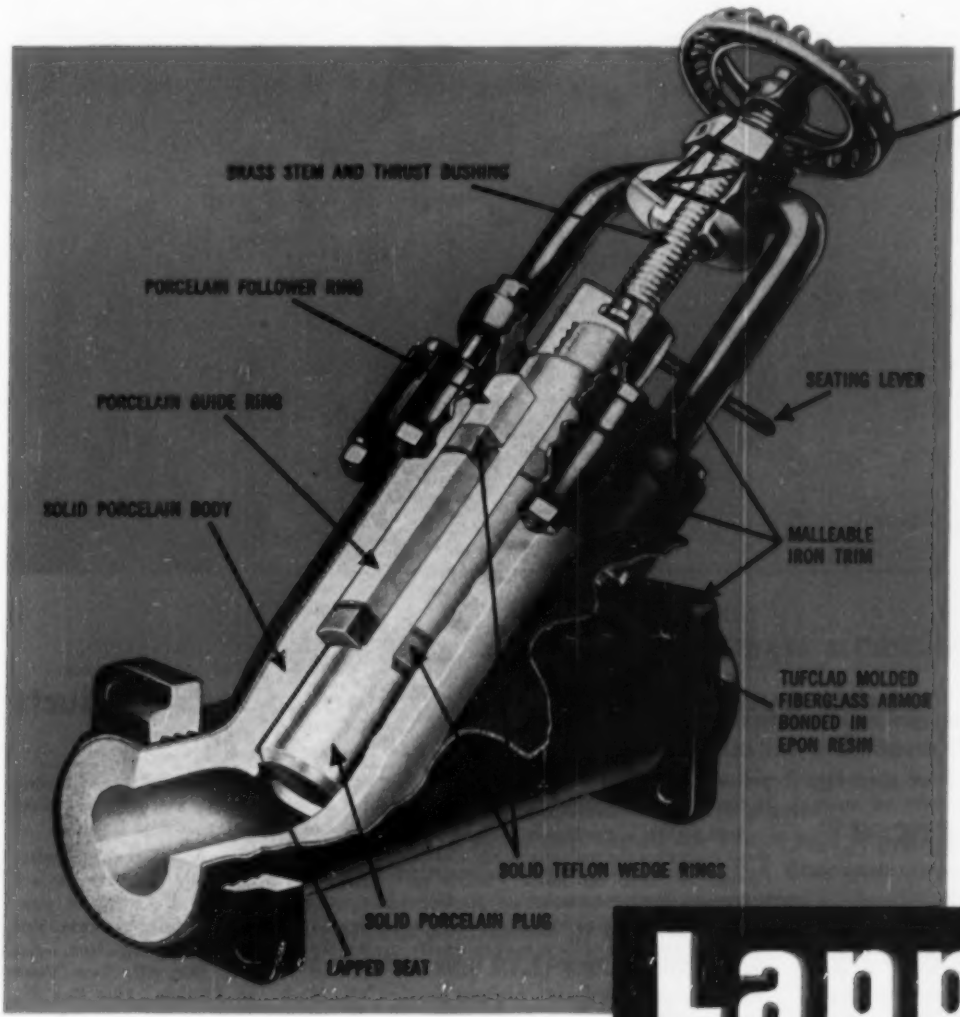

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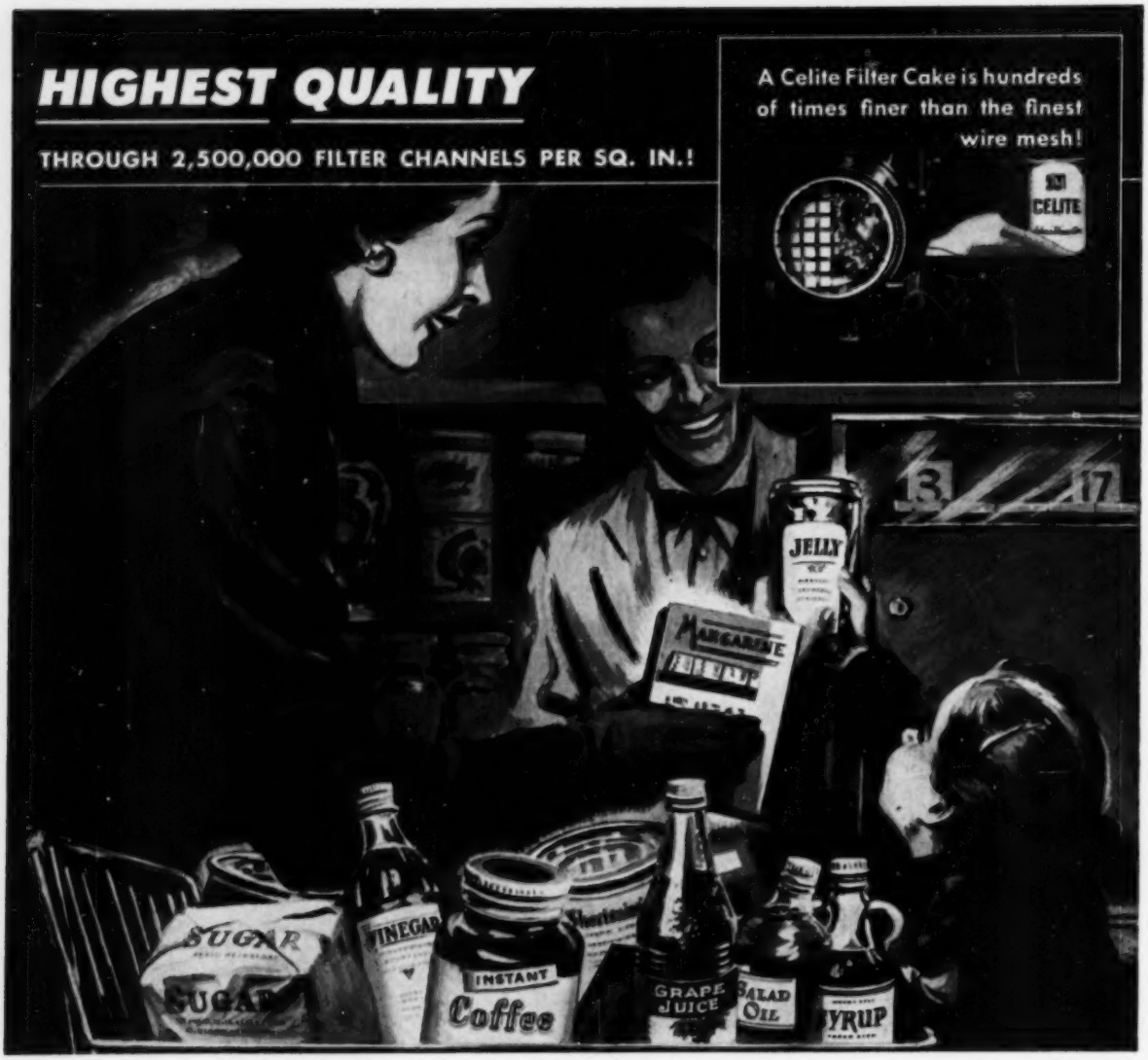

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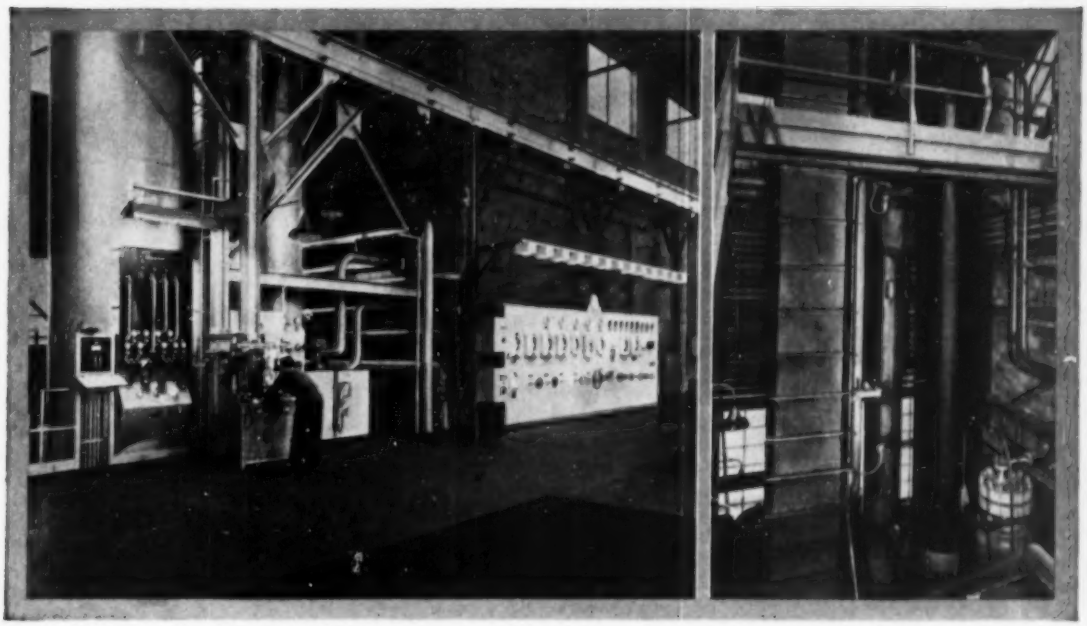

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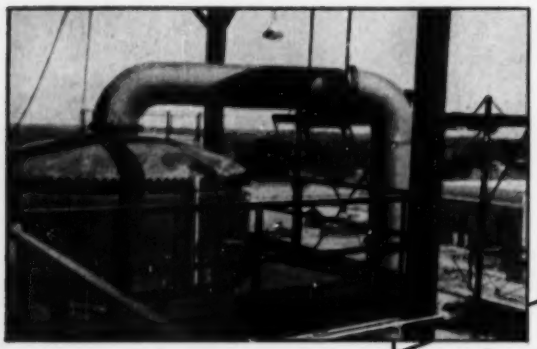

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MARGINAL NOTES

(*Continued from page 24*)

Something for the Engineers

Detergency Evaluation and Testing, J. C. Harris. Interscience Publishers, Inc., New York (1954), 210 pp. $3.75.

Reviewed by H. B. Trost, Hercules Experiment Station, c/o Research Division, Wilmington, Del.

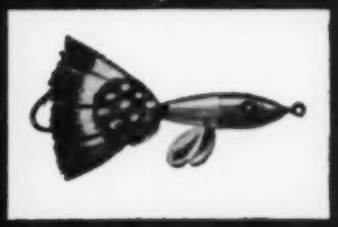
This concise, well-illustrated, easy-reading book provides both a critical survey of the current status of physico-chemical methods for the evaluation of surface-active agents as well as a manual of techniques commonly employed in evaluating the most industrially useful properties of these agents. This book, as intended by the author, does not go into the physical chemistry, synthesis, or manufacture of surface-active agents; these aspects are left to other published works.

In the introductory chapter, the author has described briefly the efforts made by technical societies and collaborating laboratories to establish standard and acceptable laboratory methods for the evaluation of surface-active agents.

Quick screening laboratory tests designed to differentiate between the properties and performance of surfactants and to serve as a guide toward selection for specific uses are covered in Chapter II.

The remaining chapters of the book deal expertly with specific evaluatory procedures and tests covering cotton and wool washing as well as hard surface cleaning of metals, painted panels, linoleum, and dishes. Well-described and referenced laboratory test methods are presented for handling the testing and evaluation of surfactants for these uses. In these method descriptions, the reader is given the benefit of background discussion and much related material garnered in the author's vigorous and energetic pursuit of this phase of the immense synthetic detergent development.

This book should prove of interest and value to the engineer, chemist, or operator involved in the synthesis, manufacture, or formulation of synthetic detergents who desire, for background sake alone, more specific information regarding detergency evaluation. Likewise, this volume should facilitate the establishment of sounder testing and evaluation techniques because from its pages may be gleaned an immense background of previous "aims" and approaches to this problem. This book will not supply an answer to every specific detergency evaluation problem, but it will contribute much related food for thought which may be applied in the attack on such problems.



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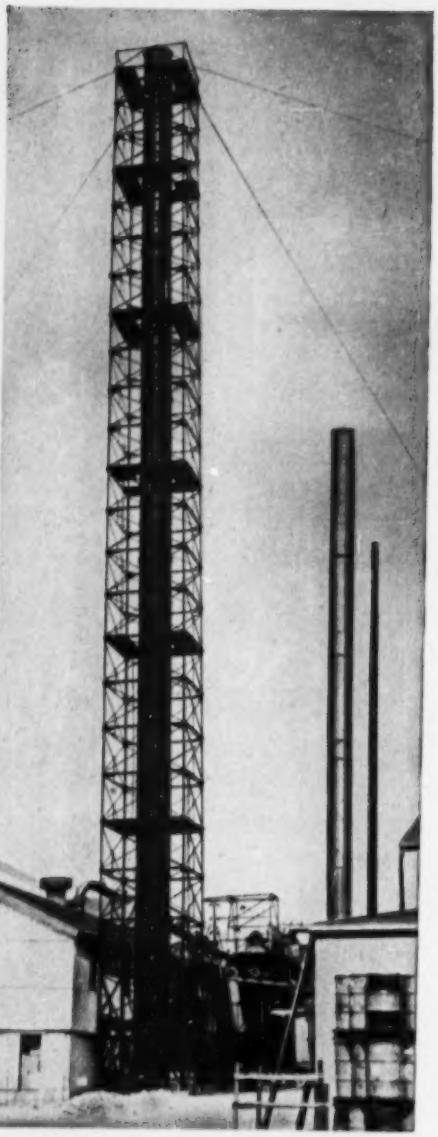

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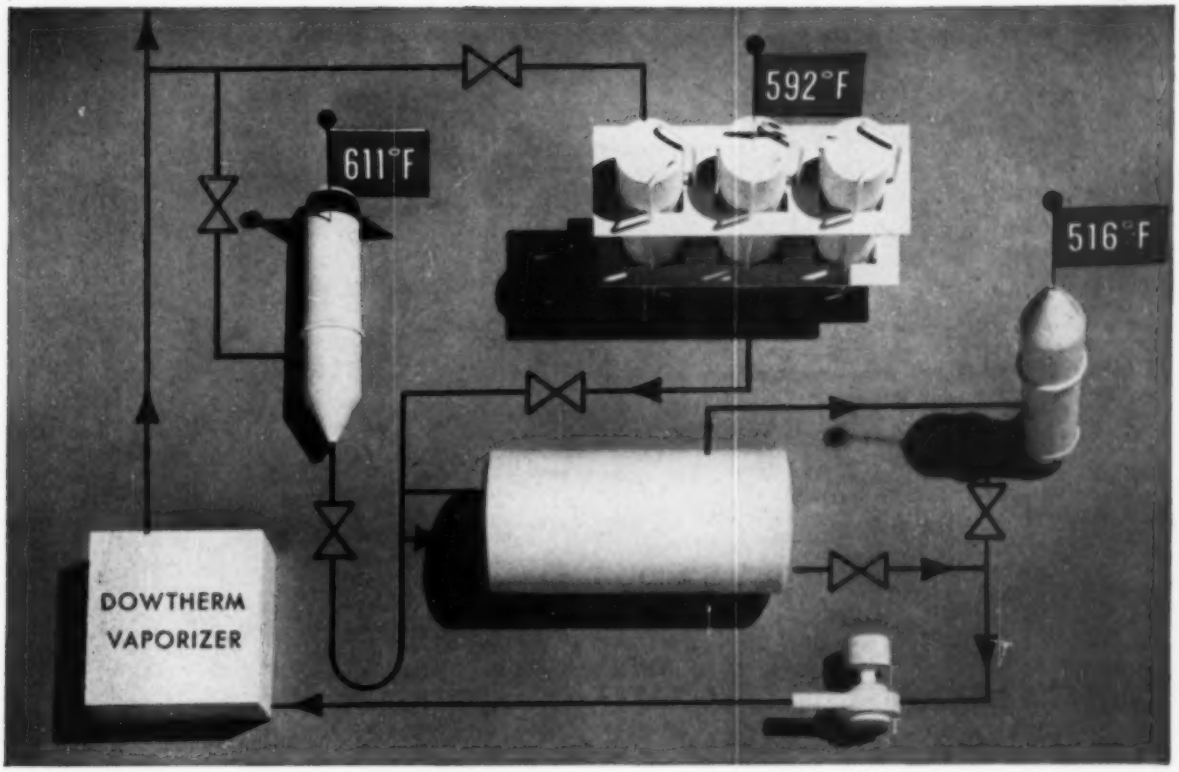

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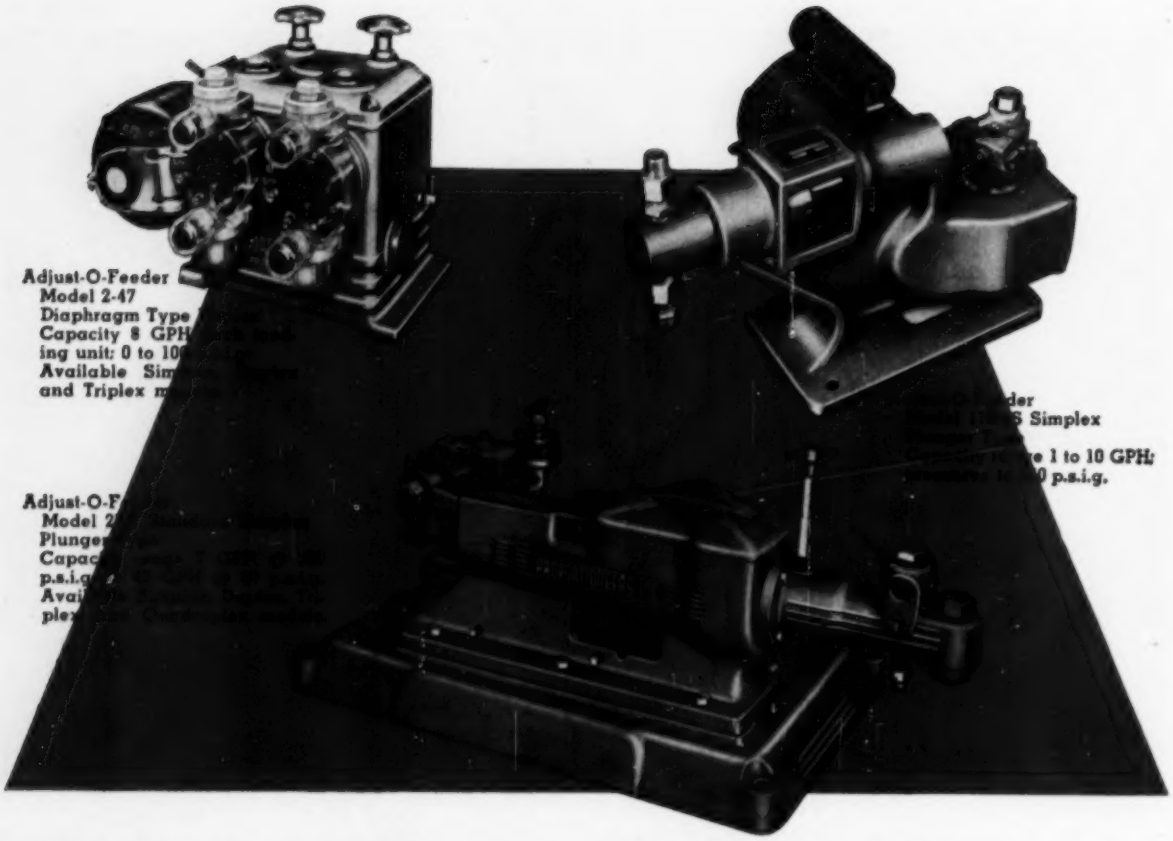

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Opinion and comment

A.I.Ch.E. Publications and The Institute

Time brings many changes, and as far as the Institute is concerned the pattern of recent years has been for the most part on the plus side. The process industries themselves have changed, doubling every five years, and the growth of the A.I.Ch.E. practically matches that. As far as Institute publications are concerned, they too are steadily growing, and the Institute offices are now in full action preparatory to beginning another publication.

In January we plan to offer a monthly magazine devoted to chemical engineering theory and experiment, one that will become a focus for the systematic exploration of the science behind chemical engineering.

The decision to begin a new magazine was not casually made. It was the subject of long and serious consideration not only by Council and the editorial staff but also by the Future of the Institute Committee under George Holbrook of DuPont and the Publication Committee under the leadership of Professor Sherwood at M. I. T. Both committees working independently came up with the same consensus, and both presented it at the Council meeting last December. The decision of Council—the profession needed yet another publication.

The publishing pattern follows well-established procedures in professional societies such as ours. Chemical engineering has been well served in the past by the *Transactions* and by *Chemical Engineering Progress*, but as industries grow and as personnel becomes more numerous and highly specialized, its needs change. In the editor's opinion the Institute is fortunate in the forthright approach of its Councils to publication problems.

Specifically the decision to begin a new publication was based on the need of a vehicle for those papers which, although important to chemical engineering, were beyond the normal everyday needs of the vast majority of chemical engineers. C.E.P. has presented some of them; yet the volumes of material available to chemical engineers has increased sharply in recent years. We have tried to solve the problem in several ways. One of them is the Symposium and Monograph Series, which has already won its place by doing a yeoman's task in presenting volumes of material at low cost to interested specialists. The most recent volume published in the Symposium series—Nuclear Engineering, Part I—has already exhausted its first printing. The very first Monograph, by Olaf Hougen, on reaction kinetics, is now going into its fourth printing.

Yet even these efforts were not enough. The A.I.Ch.E. is attracting more of the best minds in the field. It is becoming recognized as an important publication source, and with an eye to the distant future, none can deny that beginning a new journal in the classical sense is the correct thing to do.

The financial aspect of the new publication is also a case for serious study. It is not going to be easy, but at the same time the Institute can, if events develop as foreseen, find it possible to manage a new magazine. Present plans call for its issuance monthly, but these are still subject to modification. We hope to issue about 700 pages a year of highly theoretical material—first-class chemical engineering—at a cost of $4.50 to members and $9 to nonmembers. Even so, the Journal will represent a loss to the Institute, a financial drain. It will always be so, because judging by past experience, such journals are not overwhelmingly supported by the advertising of the chemical industry. The new Journal will carry advertising though, and a campaign to sell it is already under way. The money problem however is best recognized by just one set of figures in the voluminous report of the Committee on the Future of the Institute: by 1957 it estimates that the new Journal will have 1,000 pages of technical material a year and by 1965, some 2,000.

Actually the new magazine does not represent so much a subtraction of articles from *Chemical Engineering Progress* as the development and growth of the basic aspects of chemical engineering. As pure science seeks new fields, the fundamental developments in engineering sciences must be made by the engineers themselves. It is just this aspect of the profession that Council, the Publication Committee, and the Future of the Institute Committee have recognized as of paramount importance in future years.

It is the editor's opinion that the new magazine is not the final answer to chemical engineers' publication problems. If there were any final answers they would have been found many, many years ago. The profession of chemical engineering is young; it is expanding at a rate few professions can match; the work of the members of the A.I.Ch.E. has grown in importance and dollar volume as has the whole field. We expect to continue to come up with new answers.

The Symposium Series will undoubtedly continue. Those who use the Series are on the whole happy, finding it quite convenient to use just one volume for the latest research results in a particular field, rather than to go through many journals in search of wanted articles.

Therefore, the publication program of the Institute is threefold with C.E.P., the new Journal, and the Symposium Series, all serving different purposes.

As was announced last month, Professor Harding Bliss is the new editor of the Journal. His headquarters will be at Yale University but all manuscripts submitted to the Institute will come to the New York office and will be considered for all three publications. The present plan is for a centralized papers desk, from which the editors of the periodicals involved will select the articles in which they are interested. The reviewing system will be kept much the same as it is, and we hope that authors will accept gladly the decisions made on manuscript disposition.

One other item of publication interest ought to be explained to the membership: Council's action in permitting advisory groups for each publication. In the past when C.E.P. was the only publication of the A.I.Ch.E. the Publication Committee had only one magazine to study and could concentrate on its policies, purposes, and direction. Now with two magazines this task becomes impossible for one group except on a broad over-all basis; therefore, each editor has been commissioned to appoint from the membership persons capable of advising each magazine. The Publication Committee then becomes an over-all advisory group to the publisher of the A.I.Ch.E. and to Council. The committee's task will be the long-range evaluation of publications in the whole field, and the advisory boards will each evaluate the accomplishments of a single publication.

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421-D

controlling costs in construction

Ralph E. DeSimone

Construction Consultant, New York, N. Y.

Mr. DeSimone is a construction consultant in New York. Up to 1953 he had been for thirty-seven years connected with Merritt-Chapman & Scott, one of the largest construction firms specializing in marine, heavy industrial, and building construction; marine salvage; and heavy hoisting. He served successively as engineer, job superintendent, district manager, vice-president, executive vice-president, president, and director. He received a B.S. in civil engineering from New York University in 1914.

The construction industry leads all others in the United States in terms of dollar volume. Costs in an industry of this magnitude are of major importance and are controlled by many factors. Since there is no magic formula of control, each one of the many types of construction activity has its own cost problems.

This paper concerns principally heavy and industrial projects of major proportion; two phases of such projects will be considered.

1. The broad or precontract phase, in which the work is planned and a contract awarded.
2. The actual construction phase, in which the work is carried out.

Precontract Phase

Cost controls begin in the precontract phase of any project, when the owner engages an engineer or architect and acquaints him with the scope of the building plans to the extent needed to design the structure and draw up detailed plans and specifications for its construction. Unless consulted, the contractor or builder plays no part in this first phase.

Great care should be exercised in selecting the engineer-architect because of his role in cost control through engineering design. Cost control through this medium has two aspects: costs written into the plans, and cost variables which arise after actual construction begins.

Concerning the first aspect, namely costs written into the plans and specifications, it is essential that the engineer or architect make a preliminary investigation of the job site and obtain accurate data, such as borings and other conditions; thoroughly study the most modern construction methods and labor-saving devices; keep always in mind the ultimate use of the structure, so as to make a design suitable to present needs and future maintenance. Future maintenance costs are important, particularly in the chemical field, where there is rapid deterioration in materials and equipment due to corrosion.

Unless otherwise stipulated, it is assumed that the engineer's plans are complete and definite, and the specifications sufficiently descriptive to set forth precisely what the owner has in mind. Most designs are of a high degree of excellence. Some, however, do not show all details and are not flexible enough to be easily adapted to changed conditions in the field if encountered. When the design is being finalized, the owner should be certain of what he wants. Except for minor items, most changes made after work starts usually add to the cost. On certain projects it is advisable, if costs are to be controlled, that the owner have his operating or production personnel participate in the engineer's plans at this time in order to give him the benefit of their knowledge of what is required and desirable from a practical operating standpoint. In the interest of his client the engineer usually prepares a preliminary estimate of cost, which is later used for comparison with the bids or construction proposals received from contractors.

In some instances construction specialists are invited to review the initial design and engineer's estimate of cost for friendly criticism before prices are asked. This is an excellent procedure, and is no indication of weakness on the part of the designer. Many such specialists can offer constructive criticism of the design, particularly regarding costs, and can make suggestions for adapting it to regular methods of construction in the field. The designer is thus aided in looking back on his job and thinking about the construction problems involved, and he designs accordingly.

After a decision on the design is made and detailed plans and specifications are completed, they are made available to contractors from whom proposals will be received. Each contractor prepares his estimated cost for performing the work, which is the basis of his proposal or bid.

Types of Contract

The construction contract is the medium through which the owner transfers his wishes into a reality. These contracts take many forms. On public works, for example, except in times of emergency, lump sum or unit price contracts are the usual type, and are awarded on a competitive basis to the low bidder. The contracting agency generally has no choice in the selection of the contractor, provided he can qualify and obtain a bid security and performance bond.

On private work costs may to some extent be controlled through the type of contract selected, and work may be awarded with or without competition, and not necessarily to the lowest bidder, on a lump sum, unit price or cost-plus basis, with or without an incentive arrangement.

An excellent type of contract is a negotiated cost-plus-fixed-fee with a guaranteed maximum cost, and a penalty and bonus provision, provided this type is adaptable to the project. This form has obvious advantages to the owner and to the contractor, alike. Sometimes the owner prefers to act as his own general contractor. In such cases it is believed that costs are better controlled when the owner hires an experienced professional construction man to manage the project, rather than use one of his own staff.

Selection of Contractor

There are many good contractors—large and small. However, not all are qualified by past performance on similar work, nor do they have qualified operatives also experienced in the particular type of project contemplated. Not all have sufficient resources in personnel, plant, and finances to handle the work properly; to meet or beat the construction schedule; and to handle successfully any emergency which may arise, plus a good record with organized labor. Care therefore is necessary in selecting a contractor.

Speed in construction is determined largely by the skill and resourcefulness of the builder, and his performance can influence profit or loss in production.

Construction costs are influenced by the contractor's capability. They are his life blood, and only one who knows them can be expected to survive in present-day competition. Cost controls for him therefore are of prime importance.

Regardless of the type of contract used, its financial basis, or method of awarding the work, with the execution of the construction contract the builder has a definite commitment to complete a project, and his objective is to do so at or below his estimated cost.

Construction Phase

Upon notice to proceed, construction begins.

I have found that construction costs, on all but small projects, are best controlled through the method of contractor operation in which a strong field organization is utilized, headed by a competent project manager. The project manager, after approval of a general plan of operation by his superior, must be capable of "generating his own steam" and carrying out the contract with his own forces and with a minimum of assistance from the operating executive at the home office. With this procedure the operating executive follows the job through regular field reports on cost and progress, graphic charts, progress photos, frequent telephone contact with the project manager, and personal, periodic visits to the job. He interferes only when necessary and on such occasions he and his staff devote their best talents and energy to solving the problem or difficulty since costs are always involved, immediately or ultimately.

The assignment of a thoroughly competent field project manager is of the utmost importance, since results depend to a great extent upon his performance. Good men in this category are hard to find, and it pays in the long run to get the best. Cost controls are essentially dependent upon human endeavor, and it follows that the project manager, in addition to having knowledge by experience of the kind of work at hand, must possess leadership and administrative qualities and the ability to read and analyze reports, have a good business head, and be cost conscious. I believe cost-consciousness is one of the keys to successful cost control and cannot be overemphasized. The operating executive, realizing this, constantly emphasizes the point to his project manager, and expects him to develop the same sense of cost-consciousness in the minds of all under him. The project manager must be the spark which ignites and holds the enthusiasm of the entire field organization. He must have the following:

1. **A strong supporting organization, specifically geared to control costs, and particularly a good office manager, because he will be the central figure in the record-keeping part of the cost control scheme.**
2. **A competent purchasing staff to buy at or below the estimate.**
3. **A good expediting organization to avoid material delays.**
4. **Good tools and plant with which to operate, and facilities to keep the plant going. It is impossible to produce good costs with poor plant.**
5. **A good office as the field headquarters because paper work is important, particularly on large jobs.**

In the second phase of controlling construction costs the target is to meet or to better the original estimate, or suffer the financial consequences. All contractors who operate efficiently have sound cost-keeping methods and know their costs. With this knowledge they have the ability to approach and conduct today's construction procedures.

In one method used in preparing the original estimate, which has been successfully used for many years, each item, direct or indirect, is identified by an account designation, a numeral in the case of direct costs and a letter in the case of indirect costs. These account classifications are used throughout the construction operation on all reports. Other methods and designations are used by contractors, but are believed to be basically the same.

Costs can be followed and controlled during construction only by means of accurate record keeping and reports, and constant vigilance. When the job starts, various instruments of control are established, with the original estimate as their base. Scheduled progress of the various items of the contract and overall progress are plotted on graphic charts, and actual progress is recorded thereon at set intervals. A convenient form of linear progress schedule with a comparison of estimated and actual progress is made up. Job photos showing progress are taken at periodic intervals. Quite often the project manager, for his own use, has a composite diagram made from the contract plans, and plots the progress daily on the various items of the work.

Progress, however, does not necessarily mean making costs; it is necessary to analyze and meet or better the original estimate.

This is done in the first instance through the labor cost and progress report, which is confined to labor only. It is compiled daily, when possible, from information turned in by the job foremen and must be accurate. It shows items completed and unit labor cost for the reporting period, cumulative unit labor cost to date, and for comparison estimated quantities and estimated unit labor costs. It should be remembered that the chief concern of the builder is to control his labor costs, and the labor cost and progress report is an important tool to the management of a construction job. Each item in it is easily identified for comment between the home office and field through the code account designation mentioned earlier. The report is carefully reviewed by the operating executive. When any item appears out of line, or shows a tendency to get out of line, the project manager is called upon for an explanation, a daily trend chart is started on the particular item, and its progress carefully watched. These trend charts are a valuable index, and have been of such help that it is recommended that they be adopted for all items and used for future reference.

One contract is recalled where field reports received at the home office indicated costs which, if not improved, would result in a final unit cost on a major item double that which was estimated, and a very substantial loss. Immediate action was taken by establishing a trend chart, on which was plotted the daily trend of the item. It was watched carefully and methods were devised to improve the progress. The vigilance exercised focused the attention of all on the danger, and as a result of corrective measures, the cost began a downward trend, and finally came close to the estimate. Incidentally, this vigilance developed in that project manager a cost-consciousness so deep he could not thereafter lose it, even if he wanted to. This illustrates the type of cooperation between the home office and field which produces sound cost control.

A monthly report is also compiled. This is a larger and more detailed report. It shows, for the month, quantities and unit costs for labor and materials, estimated cost to complete, estimated final cost, and for comparison the original estimate. This monthly report gives a comprehensive picture indicating variations between estimated and actual costs, and a forecast of final costs. The project manager must participate in the preparation of this monthly report, since only he can forecast with assurance the cost of completion.

Reports such as those mentioned enable both the project manager and the home-office operating executive

1. To follow carefully the trend in costs on the work
2. To be alerted to cost danger signals
3. To take necessary corrective measures when costs get out of line or sections of the work fall behind schedule.

They also provide the operating executive with a means of reviewing methods and types of plant used in construction, in the light of the progress made, and this often results in constructive suggestions to the field project manager.

Other Factors Affecting Construction Costs

Factors affecting costs in construction include some already touched upon and a few others not mentioned. These include:

1. Work changes
2. Material delays
3. Labor delays
4. Failure of subcontractors
5. Engineer's (or owner's) field personnel
6. Equipment and tools
7. Job safety
8. Weather conditions
9. Errors in judgment by contractor

One aspect of control of construction costs through engineering design involves increases in costs due to work changes required when translating the design into actual construction under field conditions—a critical area where costs may be affected. One of the greatest difficulties experienced is lack of coordination of the design as a whole, especially on certain types of building projects which are highly specialized and involve a number of skills—architectural, structural, mechanical, electrical, and others. The builder in such cases is confronted with what amounts to a redesign and coordination of the work, so as to be able to proceed with its construction in an efficient and economical manner. This invariably results in great delays, and often in considerably increased costs.

Material delays are costly. They result from many causes, among which are poor scheduling, work changes, improper planning, and poor expediting.

The job purchasing agent and expediters are charged with the responsibility of getting materials to the job. They know the construction schedule which must be met to control costs. They must deal with reliable suppliers who can make deliveries when required, and thus avoid delays. Construction wages are among the highest paid today, and labor delays caused by waiting for materials can be costly.

One of the most heartbreaking delays in construction results from labor controversies. Contractors with good labor records seldom get into this trouble, but on occasion job costs are greatly increased through work stoppages beyond the builder's control, such as sympathy strikes and jurisdictional disputes. These can occur more frequently on jobs where many trades are used, particularly in the case of subcontractors.

The necessity for the builder carefully to screen his subcontractors has been mentioned. The failure of a subcontractor to perform and keep up his part of the construction operation can seriously increase costs by handicapping over-all progress and holding up other work until the general contractor can replace him, or get himself in position to take over.

Contractors find it advisable to hire the best help available, regardless of cost. It is similarly the responsibility of the engineer to entrust the interpretation of the plans and specifications only to supervisory personnel who have had practical experience with contractors and understand their methods of obtaining results; who have a cooperative rather than a policing attitude; and who have the ability and authority to make binding, on-the-spot decisions when the occasion demands. The lack of these often is a factor which creates controversies, causes delays, and increases costs.

No contractor should take on a major contract without good equipment and tools, since costs and progress can be controlled by their use. He also needs good maintenance and repair facilities to keep breakdown delays to a minimum since such delays can be costly.

A good safety record is a product of good housekeeping and watchfulness. Accidents are costly to both owner and builder. A bad experience rating increases the contractor's future insurance costs. In addition, accidents causing physical injuries to personnel or damage to the property of others can subject both the owner and contractor to lawsuits and judgments, some of which may be beyond insurance limits.

Weather conditions can materially affect costs. Although weather data are available to the builder, his only means of control in this respect is the exercise of good judgment—to know when and when not to work if the site is at an exposed location or when to shut his job down. Bad judgment often means disaster and increased costs.

Mistakes or errors in judgment by the contractor can increase costs, such as those in the design and installation of a temporary structure, wherein the structure collapses and requires tearing out and rebuilding new, or repairing equal to new, to restore the structure to its original usefulness — a considerable added cost and one that is usually paid by the contractor. The penalty for errors is often double the original cost.

Summary

I have touched only the high spots of a broad subject in an interesting and fascinating industry, and will conclude with the following recommendations for controlling construction costs:

FOR OWNER AND/OR HIS ENGINEER/ARCHITECT

1. Use great care in selecting an engineer or architect.
2. Obtain accurate data on site conditions.
3. Prepare complete and definitive plans and specifications, with maintenance problems in mind.
4. Design for erection by regular construction methods.
5. Obtain practical advice from construction specialists.
6. Decide definitely what is wanted.
7. Carefully select the most suitable type of construction contract.
8. Appoint an able field representative with practical experience, ability, and authority to make decisions.
9. Coordinate in advance any separate specialty design with field conditions in mind.
10. Eliminate or keep work changes to a minimum.
11. Make a wise selection of the contractor.

FOR CONTRACTOR

1. Run the job from the field, not the main office.
2. Assign a thoroughly competent field project manager, and a good organization under him.
3. Assign modern tools and equipment in good condition, with provision for maintenance and repair.
4. Devise simple method of cost reporting, easily identified by main office and field.
5. Develop cost-consciousness in the entire organization.
6. Exercise constant vigilance.
7. Select subcontractors carefully, weighing heavily past record and performance.
8. Avoid material delays.
9. Avoid costly errors in judgment.
10. Maintain good labor relations.
11. Enforce a safety program.
12. Maintain pleasant relations with the owner and his engineer.

(Presented at A.I.Ch.E. Springfield, Mass., meeting.)

the integration of engineering skills in chemical plant construction

Charles W. Perry, at present engineer-manager on a defense project at Niagara Falls, N. Y., has based this paper on his engineering experience with four chemical and petroleum companies.

Charles W. Perry | Project Engineer, Baltimore, Maryland

Chemical engineers work in four main divisions of the chemical process industries: manufacturing, engineering design, research and development, and sales. Often chemical engineers understand incompletely how the other branches of engineering function in the design and construction of new manufacturing facilities.

In the manufacture of chemicals or refined petroleum products, the engineering skills other than chemical, i.e., civil, mechanical, electrical, instrument, and materials, have a common meeting ground mainly in two places, the design and construction of new facilities and the maintenance and repair of existing facilities. The functions are equal in importance but different in nature. Because of the money involved and the necessity for workable facilities, however, greater engineering skill and coordination of efforts are required in the design and construction of new plants.

Types of Engineering Organizations

In the design and construction of most new process facilities, all branches of engineering are required because without any of the six engineering skills a successful design usually cannot be derived. The emphasis will vary from job to job; for instance, the electrical engineer's role in the design and construction of an electrochemical plant (such as chlorine-caustic soda) is greater than in a petroleum refinery. In both cases, however, the design will not be complete or workable without electrical engineering. In recent years recognition of the importance of instrument and materials (or corrosion) engineers has grown.

An engineering organization can be either part of a manufacturing corporation or a separate business that may or may not include construction. In the latter case it is often referred to as an "architect-engineer" and offers all the engineering skills. Contrasted with the architect-engineer is the construction contractor, who often offers only civil, mechanical, and electrical engineering skills together with labor recruiting and supervision, and construction machinery. In many cases a contractor may furnish only labor and labor supervision. In other words, a corporation may buy whatever engineering skills and services it requires beyond its own abilities to construct new facilities. This terminology is arbitrary, varying from organization to organization.

Usually small or medium-sized chemical manufacturing or petroleum refining firms buy a higher percentage of outside engineering design and construction help than do larger firms which can afford to keep an integrated group of highly skilled engineers in each branch of the profession. There seems to be a growing tendency in large process firms to use architect-engineers to an increasing extent and thereby limit the size of their own central or divisional engineering organizations. This places the problems of expanding and contracting engineering forces on the architect-engineers, which is probably where it should be. It is difficult to generalize here, however, because the largest chemical corporation in this country maintains its own large central engineering organization, which in effect acts as its architect-engineer.

Protection of Process Information

Chemical or petroleum refining firms with research facilities frequently desire to protect process information developed within their own organizations. In such cases the chemical engineering design and frequently part or all of the mechanical design is executed within the manufacturing corporations before an outside architect-engineer or contractor is called.

Organization Chart of an Architect-Engineer

Figure 1 shows an organization chart for a large architect-engineer firm offering complete service for design and construction of new chemical manufacturing facilities. Each of the functions indicated is an essential part of the business of such a firm. All the design functions are under a single director, which emphasizes the importance of coordination in this work. It is here that the engineering skills must be exercised in a coordinated manner for accurate and economical results.

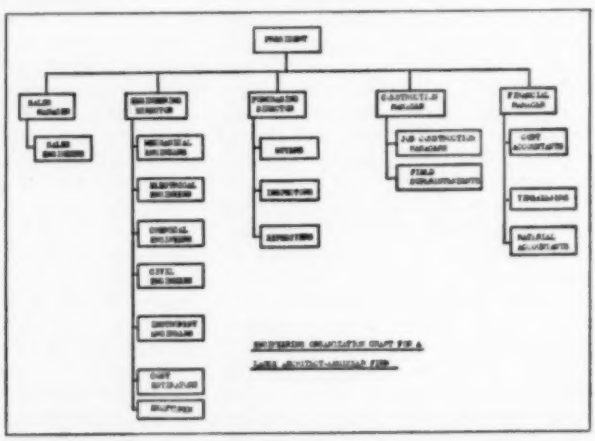

Fig. 1.

Sequence of Work in Engineering Design

The chemical engineers are required almost without exception to perform their design work first. A picture of what is to be built may be first portrayed on process flow sheets containing heat and material balances and key temperatures and pressures. At least schematically the types of process equipment are usually pictured.

Without this, the other branches of engineering cannot go to work.

The complex question as to when a pioneering type of chemical plant is ready to be constructed is important here. In the case of proven processes, such as ammonia synthesis and catalytic hydrocarbon cracking, new plants can be constructed at any time. Even here process improvements almost always are included in new units to make them to some extent experimental.

In the writer's experience a pioneering chemical plant with a capacity of several tons a day was designed and built successfully wholly from laboratory and bench scale pilot plant data. More often it is desirable to have at least some experience making several pounds a day of product before scaling up to tons a day. In most cases of a pioneering type of chemical plant, the responsibility for a firm process flow sheet must rest on a chemical engineering group in a research department. The requirements are usually less rigorous for scaling up a petroleum refining process, since the requirements for chemical purity are fewer.

When the process flow sheet is firm, the mechanical and instrument engineers can start to collaborate with the chemical engineers in preparing engineering flow sheets where major equipment sizes, pipe sizes, and major instrumentation appear. It is usually not possible to show on engineering flow sheets minor supporting equipment or details of utility requirements.

From the process and engineering flow sheets a mechanical or civil engineer can lay out the equipment in proposed structures. Then the cost estimator, who is usually a graduate engineer, can determine adequately the approximate cost of new facilities. Unfortunately, corporations often do not have enough patience to develop these three key sets of drawings before requesting appropriated money; therefore money troubles start.

In the design division engineers and draftsmen must work closely together to avoid mistakes. Nothing demoralizes a new design and construction job more than infirm process flow sheets. Changes in process after the mechanical design starts result in obsolete drawings, confusion, delays, errors, and increased engineering costs. If construction has started, they result in added costs which are often much larger than the added engineering costs.

Usually after both the chemical and mechanical engineers have their design well advanced, the civil and electrical engineers can become fully effective. The civil (or structural) engineers must support and house the equipment and personnel, which indicates that they must know what they are housing. Once an area layout or plot plan is firm, however, the civil engineers can design general facilities such as roads, fences, sewers, etc.

The electrical engineers have the responsibility of furnishing power and lighting where needed and of specifying motor and generator types and sizes and wiring for the instruments and controls. If new power generating facilities are required, the electrical engineers' work load is much greater.

Once the process equipment has been sized and specified, the design of piping can begin. Not only must the lines be sized, but the wall thickness, material, type of valves, type of safety devices, supports, and insulation must be specified. Provisions must be made for expansion and contraction of lines from heating and cooling. The piping draftsmen must be sure, for example, that they are not running pipe where the electrical draftsmen are running conduit. These points are mentioned to emphasize again the necessity for day-to-day coordination of design and construction work.

Corporation Central or Divisional Engineering Department Organization Chart

Figure 2 shows an organization chart for the central or divisional engineering department of a large multiplant corporation. From his experience in centralized engineering divisions of two major chemical companies and a major petroleum company, the writer judges that this chart represents a workable scheme with many virtues. All of the engineering skills and supporting services are represented except purchasing, which is assumed to be done elsewhere. This chart pictures a separate chemical engineering group which includes the closely allied materials- or corrosion-engineering function.

In most sizable engineering organizations, a separate construction group is often set up. The construction of large process facilities requires specialist engineers with wide experience in handling labor and modern construction tools. Such men are usually civil or mechanical engineers with a liking for such work. Since architect-engineer firms and contractors make their living largely on construction, they are generally most highly skilled in this field. The manufacturing corporations who hire architect-engineers, however, must have at least some competent construction engineers to oversee the work being done for them.

Figure 2 represents the necessary functions for an integrated corporation engineering department. Subtracting any one of the functions leaves less than a complete service available. A corporation can vary the extent to which it does detailed engineering by giving more or less work to outside engineering firms, but each branch of engineering should have at least one strong experienced spokesman.

In two major chemical corporations the recent trend has been to maintain relatively small central departments of highly skilled engineers and place the detailed work elsewhere.

How Much Engineering and What It Costs

The cost of engineering, measured in percentage of the total cost of a new facility, is a variable depending on the type and complexity of the job. It is also dependent on the amount of overhead applied by the manufacturing corporation, the architect-engineer, or both. Engineering cost here is defined to include the salaries of engineers, draftsmen, and supporting personnel; space, light and heat for them; engineering supplies; depreciation of engineering equipment; travel; field liaison; and overhead. Depending on the accounting system of a corporation, its overhead on engineering personnel salaries (the dominating cost item) has been at least 100%. It has been the writer's experience that engineering design costs exclusive of construction supervision range from 5% minimum to 15% maximum of the total cost of the job. A case where existing chemical plant facilities were duplicated in like kind gave a 5% engineering cost. A case where a pioneering chemical plant was built based on incomplete process data gave 15%.

The most convenient way to estimate how much engineering and drafting manpower is required is to work back from a dollar figure for engineering costs divided by the average salaries of engineers and draftsmen, including overhead. For architect-engineer personnel with about 120% overhead this is $100-$125 per man day worked, obviously only an approximation.

A better way is to prepare a drawing list when the job is adequately defined and relate this to drafting and design engineering man days. A rough average figure for preparing and checking a drawing on sizable chemical plant con-

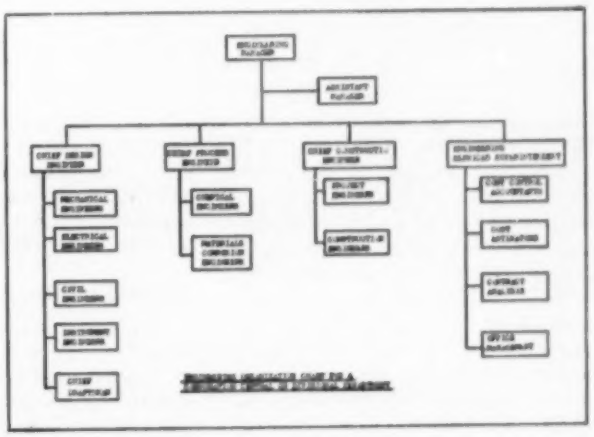

Fig. 2.

struction jobs is, the writer has found, one hundred man hours. Another approximation is that one hundred drawings are required for each $1,000,000 of investment on large chemical jobs. For small or semiworks plants the number of drawings per unit of plant cost (and therefore engineering cost) may well be higher. Again there is a vast variation from job to job.

It is interesting to examine the split of engineering and drafting costs between the different branches. In the majority of cases the mechanical engineering cost will be highest, because of the large amount of piping and pressure vessel work. This is usually, in the writer's experience, about 40% of the total, with the rest divided as follows: chemical 25%, structural 20%, electrical 10%, and instrument 5%, as a rough approximation.

Figure 3 gives an idea of typical build-ups of engineering and drafting personnel of all types for three jobs running simultaneously in an integrated engineering organization of moderate size. There is always the problem of scheduling work and obtaining new work so that major personnel expansions or contractions can be avoided. In spite of the best efforts of everyone concerned, they still happen frequently. Figure 3 indicates that the engineering manager should actively be seeking in July new work for November and December.

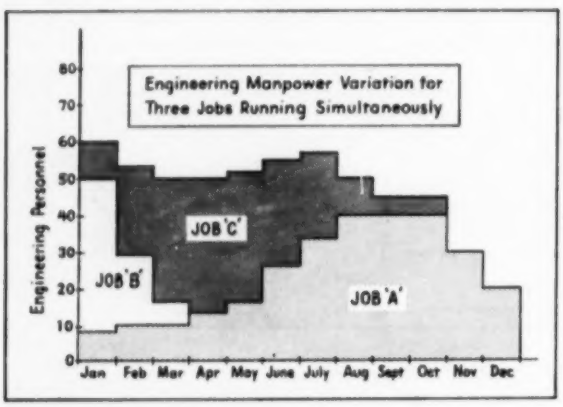

Fig. 3.

Estimating and Handling Appropriated Funds

This section might be called "The Evils of Money," since financial problems are often as severe as technical ones in chemical plant construction. The design engineers in each group must be aware continually of the relative costs of the materials and designs they originate. At the start of a job the engineering manager must set the philosophy regarding conservativeness, corrosion allowance in equipment, safety factors, extent of instrumentation, etc.

Estimating engineers base cost estimates on information available to them. The quality of a cost estimate is directly proportional to the amount of information available. An estimation within 15% is possible, the writer believes, only after about 50% of the engineering drawings are prepared; however, the majority of appropriations are obtained on less information. With firm process and engineering flow sheets and layouts a cost estimate within ±30% is usually possible. During construction many difficulties arise such as strikes, bad weather, slow material delivery, and competing jobs in an area; it is not surprising that overruns are frequent. To avoid trouble later it is desirable to advise management what the probable accuracy of an estimate is when asking for money based on it.

To keep an engineering department aware of the financial status of all jobs in progress from month to month, accountants must be employed either by the architect-engineer or the manufacturing corporation to tabulate labor and material expenditures from month to month, including money committed for future delivery of equipment and material. Often managements require monthly financial status reports and forecasts for planning capital expenditures. These in turn require forecasting by the construction manager and cost estimating of labor forces on each job.

A typical construction manpower profile for any sizable job will follow the same type of expansion and contraction as Job "A" in Figure 3 for engineering personnel except that the numbers required will be much greater.

Obtaining the Necessary Labor

Planning whether or not part or all of a chemical plant construction job is to be contracted for outside raises the question of existing or expanded plant forces doing large jobs when the jobs are adjacent to existing facilities. Considerable experience with expanded plant forces leads the writer to the conclusion that labor requirements for all sizable jobs should be contracted for outside. A major advantage of a contractor or architect-engineer is that he can expand and contract his labor forces to suit needs without elaborate recognition of the seniority systems in effect in most plants. And thus he usually obtains greater labor efficiency.

A rule of thumb employed by a major petroleum corporation is that no job over $100,000 should be done by a plant engineering department with existing or expanded maintenance forces. An ability to handle a job of greater magnitude in this company would indicate an oversized plant engineering group.

Types of Contracts

On the assumption that either engineering design and/or construction work is to be contracted for outside, the question of type of contract arises. Basically there are only three types: (1) cost plus a percentage of cost, (2) cost plus a fixed fee, and (3) lump sum. A variation between (1) and (2) is a bonus or penalty arrangement for construction jobs, wherein the contractor obtains an extra fee for finishing in a certain length of time or for saving a certain amount of money, and loses a certain amount if time or money is exceeded.

Cost-plus-a-percentage-of-cost contracts are unpopular with many companies. Lump sum contracts are popular with many companies. They require that the engineering design on a job be well defined, however, which usually means completion of a high percentage of the drawings. When this information is lacking, a cost-plus-a-fixed-fee contract is most feasible.

Plant Start-Up

Finally, and often later than expected, the new chemical facility will be ready to start up. The design chemical engineer, after completion of his process and engineering flow sheets, will have been required continually during the design and construction period to collaborate with the other engineering groups in day-to-day design questions.

In chemical companies the chemical design engineers are often required to assist in the start-up, at least in a consulting capacity, to improve on weaknesses in design as they appear. After he goes through the design and construction with all the other engineering skills there is no greater satisfaction for a chemical engineer than to see a facility placed in operation.

the conversion of ethylene to ethanol

The Direct Catalytic Hydration of Ethylene in the Vapor Phase

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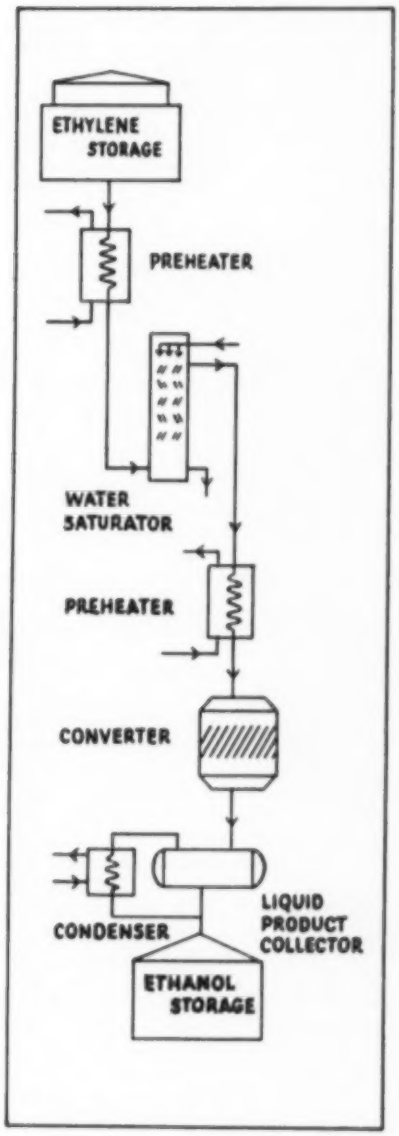

The direct hydration of ethylene in the vapor phase has been investigated up to 650° F. and 2500 lb./sq. in. over catalysts supported on alumina and silica. Ethanol was the principal product with all of the catalysts studied. WO_3-SiO_2-gel catalysts were the most active, particularly at lower temperatures, which favor the equilibrium.

Ethanol yields amounting to 4.0 mole %, 50% of the equilibrium value, were obtained from the WO_3-SiO_2-gel catalysts at 580° F., 2000 lb./sq. in., steam to ethylene ratios of about 1.0, and space velocities of 1500 reciprocal hr. Higher temperatures and/or pressures did not increase the yield at the same space velocity.

A rate equation for hydration over the WO_3-SiO_2-gel catalyst was established from conversion data at four temperatures from 508 to 580° F. It indicated that hydration proceeds by a surface reaction without preferential adsorption of ethylene or water and without retardation by strong adsorption of ethanol. The apparent energy of activation was approximately 30 kcal./g. mole.

Mr. Mace is associated with Philip Morris Co., Research and Development Dept., Richmond 15, Va., and Professor Bonilla with Columbia University, New York 27, N. Y.

This paper records an experimental catalyst study and a kinetic analysis of the hydration of ethylene in the vapor phase conducted under essentially isothermal conditions in a flow reactor. These studies were made because of the interesting commercial possibilities of a direct catalytic hydration process for the production of ethyl alcohol. In the year 1949 nearly 100,000,000 gal. of 190 proof industrial alcohol were produced synthetically from ethylene by absorption in sulfuric acid and subsequent hydrolysis. The direct process permits smaller equipment and lower utility costs and avoids the undesirable fumes produced on reconcentration of the dilute sulfuric acid and the corrosion resistant materials required in the ethyl sulfate process. Since this study was initiated, at least three large chemical concerns in the United States have started direct hydration, but details of the processes have not been published.

The kinetic analysis was undertaken to provide data for the design of a possible commercial plant. No kinetic studies have been published on this process except for meager and uncertain data in the patent literature. It was anticipated that the experimental results could be correlated by the use of kinetic relations developed in current procedures for determining flow reaction kinetics (*8, 10, 11*).

Equilibrium Data

A number of equilibrium experiments on the vapor phase hydration of ethylene are reported in the literature (*2, 4, 14, 15, 17*), as well as equilibrium values calculated from available thermodynamic data (*3, 5, 13*). Figure 1 is a log-reciprocal plot of the values of K_f, the equilibrium constant in terms of fugacities against absolute temperature.

The solid line in Figure 1, drawn by Dodge (*5*) through the points, corresponds to the equation:

$$\Delta F^\circ = -RT \ln K_f = 28.6\ T - 9{,}740. \qquad (1)$$

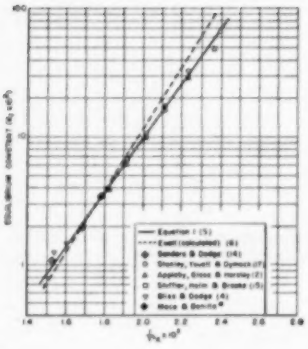

Fig. 1. Effect of temperature on the thermodynamic equilibrium for the hydration of C_2H_4 in the vapor phase.

$$K_f = (f_{C_2H_5OH}/f_{C_2H_4} \times f_{H_2O}).$$

Asterisk designates ethanol dehydration only; all others approached equilibrium from both sides.

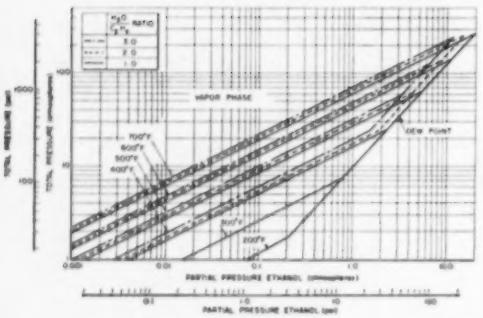

Fig. 2. The effect of varying total pressure on the equilibrium partial pressure of ethanol at different temperatures and mole ratios.

Equation (1), which also agrees almost exactly with the values of K_f selected by Vvedenski and Feldman (*19*), was adopted in this study. The fugacities required to compute K_f were obtained by multiplying the mole fraction of each constituent by its fugacity from Newton's curves (*12*) for the pure component at the same temperature and total pressure. This follows the assumption that the gases form ideal solutions such that the fugacity coefficient of each component is the same at its partial pressure as at the total pressure, an assumption which has been shown by Ewell (*6*) to be reasonable. The equilibrium partial pressure of ethanol was calculated and plotted in Figure 2 vs. temperature and total pressure for initial ethanol-free H_2O/C_2H_4 mole ratios of 1, 2 and 3, yielding the families of straight lines shown with a slope of 0.5.

Since high pressures and low temperatures shift the equilibrium towards higher ethylene conversions, but the presence of liquid phase may have adverse effects on catalysts, it is desirable to know the dew point of the equilibrium mixture as a function of temperature and pressure. The equilibrium-vapor-liquid compositions of the binary system ethanol-water found by Griswold, Haney, and Kline (*9*) up to 530° F. were extended in the low ethanol range by the method of Carlson and Colburn as reviewed by Dodge (*5*). The ethylene in the vapor was neglected. The calculated dew points, plotted on Figure 2, yielded the straight lines of slope approximately 1 shown as the right-hand limits of the equilibrium composition curves. The dew points from 530 to 700° F. were obtained by extrapolation. The reaction of ethylene hydration at constant pressure plots as horizontal travel towards the right on Figure 2. Therefore, any superheated mixture on the ethylene side of equilibrium will not show condensation during reaction if the final equilibrium is to the left of the appropriate dew point curve in Figure 2.

Catalysts

Numerous solid catalysts have been reported capable of hydrating ethylene in the vapor phase but their commercial utility cannot be judged because reliable rate data do not exist. Catalysts reported most active for the hydration of ethylene up to 650° F. and 3000 lb./sq.in. are WO_3 and MoO_3 on SiO_2, prepared from the heteropolyacids (*18*), cadmium metaphosphate (*2, 18*), chromephosphoric acid on SiO_2 (*18*), phosphoric acid on SiO_2 (*18*), and Al_2O_3 and WO_3—Al_2O_3 (*4, 14*).

Table 1.—Catalysts Prepared for Hydration of Ethylene (C = coprecipitated; S = soaked)

No.	Promotion method	Activation temp., ° F.	% Composition and promotion solutions used
A. WO_3—Al_2O_3-gel Catalysts			
6A-6D	None	1100	100% Al_2O_3-gel
12A	C	1100	90 Al_2O_3 and 10 WO_3, from Al_2O_3-gel and $Na_2WO_4 \cdot 2H_2O$
13A	S	680	74.0 Al_2O_3 and 26.0 WO_3, from Al_2O_3-gel and phosphotungstic acid
15A	C	1100	75.4 Al_2O_3, 24.1 WO_3 and 0.7 SiO_2 from Al_2O_3-gel and silico-tungstic acid
15B	C	1100	50.0, 49.0 and 1.0 prepared like 15A
14A	S	680	74.0, 25.4 and 0.6 from Al_2O_3-gel and silico-tungstic acid
14B	S	680	77.2, 22.3 and 0.5 prepared like 14A
B. Commercial Alumina Catalysts			
3A-3E	..	950	72 Al_2O_3, 26 WO_3 and 2.0 NiO, from German hydrogenation catalyst
7A	..	....	95 Al_2O_3 and 5 SiO_2, Harshaw
11A	..	....	100 Al_2O_3, Harshaw
17A	..	....	95 Al_2O_3, 5 WO_3
8A	..	....	90 Al_2O_3, 10 WO_3
16A	..	....	85 Al_2O_3, 15 WO_3
23A	..	....	75 Al_2O_3, 25 WO_3
24A	..	....	50 Al_2O_3, 50 WO_3
C. SiO_2-gel Catalysts from Desiccant Gel			
4A	S	650	90.0 SiO_2, 7.5 WO_3, 2.5 ZnO, German hydration catalyst
5A	S	650	78.0 SiO_2, 22.0 WO_3, from SiO_2 and phosphotungstic acid
5B	S	850	87.6 SiO_2, 12.4 WO_3, from SiO_2 and phosphotungstic acid
26A	S	600	74.0 SiO_2, 26.0 WO_3, from SiO_2 and silicotungstic acid
26B	S	850	74.5 SiO_2, 25.5 WO_3, from SiO_2 and silicotungstic acid
25A	S	600	87.1 SiO_2, 12.9 MoO_3, from SiO_2 and phosphomolybdic acid
25B	S	850	89.2 SiO_2, 10.8 MoO_3, from SiO_2 and phosphomolybdic acid
28A	S	600	88.7 SiO_2, 11.3 WO_3, from SiO_2 and $Na_2WO_4 \cdot 2H_2O$
D. SiO_2-gel Catalysts Prepared from Intermediate Density SiO_2			
29D	S	600	94.7 SiO_2, 5.3 WO_3, from SiO_2 and silicotungstic acid
29G	S	600	85.9 SiO_2, 14.1 WO_3, from SiO_2 and silicotungstic acid
29A	S	600	71.3 SiO_2, 28.7 WO_3, from SiO_2 and silicotungstic acid
29E	S	850	95.8 SiO_2, 4.2 WO_3, from SiO_2 and silicotungstic acid
29H	S	850	87.2 SiO_2, 12.8 WO_3, from SiO_2 and silicotungstic acid
29B	S	850	72.5 SiO_2, 27.5 WO_3, from SiO_2 and silicotungstic acid
29F	S	1100	96.6 SiO_2, 3.4 WO_3, from SiO_2 and silicotungstic acid
29I	S	1100	87.5 SiO_2, 12.5 WO_3, from SiO_2 and silicotungstic acid
29C	S	1100	73.3 SiO_2, 26.7 WO_3, from SiO_2 and silicotungstic acid
29J-M	S	600	82.5 SiO_2, 17.5 WO_3, from SiO_2 and silicotungstic acid
E. Other Catalysts			
1B	..	1100	40.0 NiO + 60.0 WO_3, Shell hydrogenation catalyst
9A	..	....	40.0 Co + 10.0 ThO_2 on kieselguhr, Harshaw

Difficulties were reported with ethylene polymerization and/or low space time yields over all except the heteropolyacid catalysts. Ethylene conversions as high as 86% were reported by Tanner (*18*) for the heteropolyacid catalysts. Active catalysts resulted when the complex anion of the heteropolyacid included one element from group VI, subgroup *A* of the Periodic Table, such as Cr, Mo and W.

Tungsten and molybdenum oxides supported on alumina, alumina-gel, and silica-gel were used in these hydration experiments. Harshaw WO_3—Al_2O_3 catalysts containing from 5 to 50% WO_3 were used. WO_3—Al_2O_3—gels having up to 50% WO_3 were also prepared by impregnation and by coprecipitation with phosphotungstic and silicotungstic acids. WO_3—SiO_2—gel catalysts containing up to 30% WO_3 were prepared by soaking in silicotungstic and phosphotungstic acids the SiO_2-gel carrier previously wet out by steaming. Different density silica-gel carriers were used, and the activation temperature and percentage composition varied. The MoO_3—SiO_2-gel catalysts were prepared by soaking the SiO_2-gel in phosphomolybdic acid. The more important catalysts are listed in Table I. C.P. grade chemicals were used in the preparation of all the catalysts tested.

The Wo_3—SiO-gel catalyst selected for the kinetic studies (*29* J, K, L and M in Table 1) contained approximately 17.5% WO_3 by weight. It was prepared from silicotungstic acid as follows: 28.6 g. of dry intermediate density SiO_2-gel obtained from the Davison Chemical Co., screened 6 to 12 mesh, was steamed for 6 hr. at 200° F. and then soaked in a solution containing 8 g. $SiO_2.12WO_3.26H_2O$ dissolved in 34.0 g. distilled water. After drying for 24 hr. at 230° F. it was activated at 600° F. for 3 hr. in a muffle furnace in air. The bulk density of the catalyst was approximately 0.55 g./cc.

Flow-System Kinetic Equations for High-Pressure Reactions

In gas-phase heterogeneous reactions, chemical change usually proceeds by the formation of an activated complex, and the over-all process may be divided into five different steps, any one of which may control the reaction rate (*11*):

1. mass transfer of the reactants in the gas phase ot the surface of the catalyst,
2. activated adsorption of the reactants on the active sites of the catalyst,
3. chemical reaction between adsorbed reactants to form adsorbed products,
4. desorption of product molecules, and
5. mass transfer of the product from the surface of the catalyst to the gas phase.

The rate of adsorption, desorption, or the surface reaction is usually controlling in flow systems using beds of finely divided catalysts.

Rate equations can be developed from simple adsorption theory if it can be assumed that the active catalyst sites are not competitive and behave similarly. In the reaction

$$H_2O(g) + C_2H_4(g) \rightleftarrows C_2H_5OH(g)$$

represented by $A + B \rightleftarrows R$

the surface reaction will be assumed rate controlling. When

L = number of molal active sites per unit catalyst mass,

s = number of adjacent or dual active sites per site,

C_L = number of vacant molal active sites per unit catalyst mass,

f_A, f_B, f_R = fugacity of the respective components in the fluid at the interface, assumed equal to the fugacity in the main gas stream (neglects diffusional resistance),

C_A, C_B, C_R = surface molal concentration of molecules A, B and R, moles per unit catalyst mass,

k = surface reaction velocity constant,

then sL is proportional to the concentration of dual active sites, C_A/L to the fraction of sites occupied by A, and the rate of the forward surface reaction between adjacently adsorbed molecules A and B is

$$r_1 = ksL(C_A/L)(C_B/L) = ksC_AC_B/L. \quad (2)$$

Similarly, the rate of the reverse monomolecular surface reaction between R and the vacant adjacent active sites is

$$r_2 = k'sC_RC_L/L. \quad (3)$$

When r equals the moles ethanol formed per unit of catalyst mass per hour, the net rate for the forward reaction is:

$$r = (r_1 - r_2) = ks(C_AC_B - C_RC_L/K')/L \quad (4)$$

where K' is the equilibrium constant of the surface reaction and equals $k/k' = C_RC_L/C_AC_B$ at equilibrium. The surface concentration of each component must be proportional to its fugacity and to C_L. Thus

$$K_A = C_A/f_AC_L,\ K_B = C_B/f_BC_L,\ K_R = C_R/f_RC_L \quad (5)$$

where K_A, K_B and K_R are designated adsorption equilibrium constants. When they are substituted the rate equation becomes

$$r = ks(K_AK_Bf_Af_B - K_Rf_R/K')(C_L^2)/L \quad (6)$$

But

$$C_L = L - (C_A + C_B + C_R) = L/(1 + f_AK_A + f_BK_B + f_RK_R) \quad (7)$$

and

$$K' = K_fK_R/K_AK_B. \quad (8)$$

When these expressions for C_L and K' and a catalyst fouling factor E are substituted in Equation (6), the rate equation becomes:

$$r = [EksLK_AK_B/(1 + f_AK_A + f_BK_B + f_RK_R)^2](f_Af_B - f_R/K_f) \quad (9)$$

Further simplification by substituting an over-all reaction rate constant Z for ksL gives

a. surface reaction controlling

$$r = [ZEK_AK_B/(1 + f_AK_A + f_BK_B + f_RK_R)^2](f_Af_B - f_R/K_f) \quad (10)$$

and by similar procedures the following rate equations can be developed:

b. adsorption of A controlling

$$r = [Z_AE/(1 + f_BK_B + \frac{f_BK_A}{f_BK_f} + f_RK_R)](f_A - f_R/f_BK_f) \quad (11)$$

c. adsorption of R controlling

$$r = [Z_RE/(1 + f_AK_A + f_BK_BK_RK_f)](f_Af_BK_f - f_R) \quad (12)$$

where Z_A and Z_R are the corresponding over-all adsorption rate constants for the specific catalyst.

Equation (10) indicates that the reaction rate should become greater as the fugacity of A or of B is increased, as would be expected in a surface reaction in which neither the reactants nor the products are strongly adsorbed. Increasing f_B in Equation (11) would not change the rate appreciably, as it depends primarily on the rate of adsorption of A. The dependence of the rate in Equation (12) upon the fugacity of R as well as of A and B is characteristic of reactions retarded by strong adsorption of a product.

These rate equations, involving assumptions which cannot be rigorous, are necessarily idealized. However, if one of them should agree fairly well with the experimental data over a wide range of conditions, this would constitute rather good evidence that the mechanism assumed in deriving the rate equation was correct.

Apparatus and Operating Procedure

The apparatus was designed to reach 700° F., 3000 lb./sq.in., space velocities varying from 200 to 20,000 hr.$^{-1}$, and steam to ethylene ratios from 0.5 to 3.0. Larger steam to ethylene ratios could be used in low pressure runs.

The system is shown in Figure 3. A type UM 2F Hills-McCanna pump injected water into a standard 2-cu.ft. gas cylinder, compressing the ethylene therein to 4000 lb./sq.in. The ethylene, the U. S. Industrial Chemicals C.P. grade produced by dehydration of ethanol, averaged 99.5% C_2H_4 with balance largely N_2 and CO_2. The ethylene passed through two traps to remove any traces of condensable compounds which might poison the catalyst and then through a manually controlled needle valve with which the reaction pressure was regulated. It was next preheated in a coil of 0.25-in. O.D. Monel tubing immersed in a bath of hot Meproline oil and bubbled through water maintained at the proper temperature to obtain the desired H_2O/C_2H_4 ratio. The ethylene-steam mixture was then passed through electrically heated and thermally jacketed lines to a second preheater, where the desired reaction temperature was attained, and to the converter. The converter consisted of 0.49-in. I.D. Monel pipe welded to steel flanges, and the catalyst volume could be varied between 10 and 30 cc. by spacers made from stainless steel screening. The converter, which had three thermocouples welded to the outside along its length, was surrounded by an air chamber and a large heated jacket, which kept it adiabatic.

The reaction products passed into a water-jacketed sample collector, the condensed liquid issuing at the bottom to a trap and the uncondensed vapors going on to a long tubular condenser and a second sample collector. The noncondensables expanded through a manually controlled needle valve to atmospheric pressure, passing through a capillary flow meter and a wet-test meter before being sampled and discarded. During the preliminary portion of each run no liquid product was allowed to accumulate in either collector. When conditions had become stabilized, however, the valves at the bottom of the collectors were closed and liquid samples were retained over the hour or two duration of the run.

Analytical Procedure

The volume and weight of the liquid product from each run were recorded. The liquid was then diluted with water and any ethylene polymer thrown out was decanted and weighed. An aliquot of the product was tested qualitatively for aldehydes and ketones with alcoholic sodium bisulfite. The remaining liquid was then analyzed for diethyl ether, ethanol, and water by fractionation in an analytical distilling column at high reflux ratio.

A sample of the exit gas was stripped of heavier olefins by 87% sulfuric acid and of carbon dioxide by potassium hydroxide solution in an Orsat apparatus. It was then analyzed for ethylene by the method of Francis and Lukasiewicz (7) by use of a solution of mercuric-sulfate in 22% sulfuric acid. Heavy olefins and CO_2 were never found in appreciable amounts. Saturated hydrocarbons were never indicated nor analyzed for.

The moles of unreacted ethylene were calculated from the wet-test meter readings and the percentage of ethylene. The total inlet moles were those unreacted plus those required for the observed ethanol, ether, and polymer. The inlet water was that found in the distillation plus that in the ethanol and ether. The space velocity, S_V, is the moles of inlet water and ethylene per hour converted to cc. of ideal gas at 0° C. and 760 mm. and divided by the volume of the catalyst in cc.

The total pressure was controlled to within ±2% by manual operation of the valves. Cumulative gas flow was measured within ±0.5% and momentary fluctuations did not exceed ±5%. The ethylene gas analysis was accurate to ±2.0%, and the ethanol and ether in a sample containing at least 2.0 ml. of ether were determined within ±2%, as shown by known blanks.

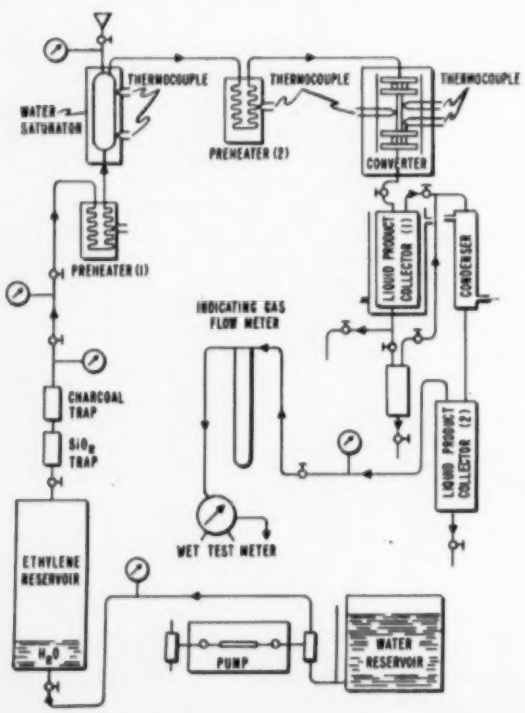

Fig. 3. Schematic flow sheet of high-pressure apparatus.

Experimental Correction Procedures

It was desirable to obtain experimental data at identical conditions for reliable comparison of the different catalysts. Since this was not always achieved, the observed ethanol yields were corrected to a standard catalyst activity level, a H_2O/C_2H_4 mole ratio of 1.0, and a space velocity of 1500 hr.$^{-1}$ when they were not far removed from these standard conditions. For the activity correction, each catalyst was submitted to an initial check run of 30 min. at the standard conditions and frequent subsequent check runs. Variations in the activity level from one catalyst sample to another and changes in activity during use were corrected by introducing a fouling factor *E*. *E* was expressed as the ratio of space velocities which would give the same ethanol yield with the test and the standard catalysts. It is more descriptive (*11*) of the properties of the catalyst than is the ratio of yields at the same space velocity.

In most instances correction to the standard space velocity of 1500 hr.$^{-1}$ was carried out from curves already obtained over a range of space velocity. In the other cases use was made of the fact that the logarithm of the ethanol yield was approximately proportional to the logarithm of the space velocity.

When the observed mole ratio was between 0.5 and 2.0, the ethanol yield was corrected to a mole ratio of 1.0 by the assumption that the reaction is homogeneous and first order with respect to C_2H_4 and H_2O and that the fugacities are equal to the partial pressures. Hence,

$$r = k_r(P_A \cdot P_B) \tag{13}$$

where P_A = the partial pressure of H_2O, and P_B = the partial pressure of C_2H_4. At constant temperature and for ethanol yields smaller than 5%, the right side of Equation (13) is nearly constant. Designating the ethylene-water mole ratio $P_B/P_A = R^*$, and the total pressure P, one obtains by simultaneous solution:

$$P_B = \frac{R^*P}{R^* + 1}, \quad P_A = \frac{P}{R^* + 1}. \tag{14}$$

By substitution in Equation (13), the reaction rate for a given temperature and pressure is given by

$$r = k_r \frac{R^*P^2}{(R^* + 1)^2}. \tag{15}$$

At $R^* = 1$, $r = k_rP^2/4$.

To correct the percentage ethanol yield when R^* is not equal to one, it was multiplied by the ratio $(R^* + 1)^2/4R^*$. The correction is small, for in an extreme case in which $R^* = 2.0$ the yield would be multiplied only by 9/8 to give the yield at $R^* = 1.0$. Although the correction was derived for a homogeneous reaction, it seemed quite adequate for this heterogeneous reaction.

Experimental Results

A. CATALYST ACTIVITY

The ethanol yields obtained at standard conditions over the different catalysts are given in Table 2 and plotted in Figure 4. The catalysts containing WO_3 on silica gel, were evidently all sufficiently active to have commercial interest, but there is a significant effect

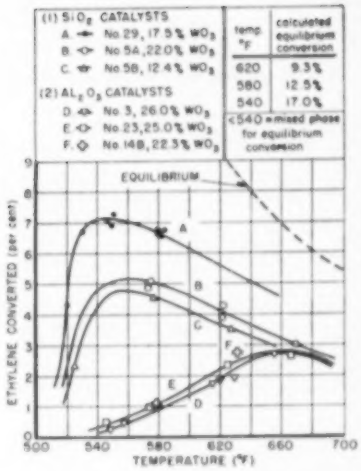

Fig. 4. Effect of increasing temperature on C_2H_4 hydration over WO_3—SiO_2 and WO_3—Al_2O_3 catalysts at 1515 lb./sq.in., H_2O/C_2H_4 mole ratio = 1 and space velocity = 1500 reciprocal hr.

Table 2.—Comparison of Different Catalysts for C_2H_4 Hydration at 1515 lb./sq. in., 1500 hr.$^{-1}$ Space Velocity and C_2H_4/H_2O Ratio of 1.0

A. Effect of % WO_3 and Preparation Method in Al_2O_3-gel Catalysts

Run No.	Catalyst No.	Promoter type	Catalyst * %	Act. T. °F.	Wt. g.	Temp. °F.	Ethanol yield mole %	C_2H_4 conv. %	Equil. C_2H_4 conv. %	% C_2H_4 conv. to polymer
63	5A	None	0.0	1100	18.4	660	0.10	0.27	7.4	0.1
72	12A	NW-C	10.0	11	11	662	0.24	0.40	7.3	0.1
89	13A	PW-S	26.0	680	24.9	661	1.53	3.02	7.4	1.0
74	14A	SW-S	25.4	11	24.8	660	1.44	2.84	7.4	1.0
78	15A	SW-C	27.0	1100	23.6	660	1.23	2.43	7.4	1.0
100	15B	SW-C	49.0	11	36.7	661	1.46	2.88	7.4	1.0

B. Commercial Alumina Catalysts with WO_3 and SiO_2

51	3B	WO_3-G	26.0	950	21.2	656	1.41	2.74	7.6	0.5
24	3A	WO_3-G	26.0	950	20.8	620	0.92	1.82	9.6	0.2
37	11	WO_3-G	26.0	950	20.7	548	0.15	0.30	16.7	0.1
68	7A	SiO_2-H	5.0	....	20.4	661	0.37	0.74	7.4	0.1
57	11A	Harshaw	0.0	....	22.3	657	0.11	0.26	7.6	0.1
87	17A	WO_3-H	5.0	....	25.0	660	0.09	0.24	7.4	0.1
59	8A	WO_3-H	10.0	....	25.5	656	0.52	1.03	7.6	0.1
83	16A	WO_3-H	15.0	....	28.0	662	1.14	2.25	7.3	1.0
118	23A	WO_3-H	25.0	....	28.3	666	1.37	2.70	7.1	0.7
125	24A	WO_3-H	50.0	....	37.5	662	1.30	2.58	7.3	1.0

C. SiO_2 Catalysts from Desiccant SiO_2-gel with WO_3 and MoO_3

64	4A	WO_3-G	7.5	650	25.3	625	0.11	0.25	9.3	0.1
110	5A	WO_3-PW	22.0	650	27.0	621	1.97	3.87	9.5	0.7
130	5A	WO_3-PW	22.0	650	26.3	575	2.61	5.10	13.3	0.6
145	5C	WO_3-PW	13.9	600	25.3	577	3.20	6.20	13.0	0.5
134	25A	MoO_3-PM	12.9	600	24.5	577	0.22	0.45	13.0	0.1
140	26A	WO_3-SW	26.0	600	30.1	576	3.10	6.01	13.2	0.5

D. Effect of Varying % WO_3 and Activation Temp. in SiO_2 Catalysts Prepared from Intermediate Density SiO_2-gel and Silicotungstic Acid

149	29D	WO_3-SW	5.3	600	14.7	575	1.91	3.75	13.3	0.4
150	29G	WO_3-SW	14.1	600	16.3	575	3.51	6.79	13.3	0.5
195	29K	WO_3-SW	17.5	600	11.0	578	3.50	6.76	12.8	0.5
143	29A	WO_3-SW	28.7	600	19.8	575	3.15	6.11	13.3	0.6
151	29H	WO_3-SW	12.8	850	16.3	577	2.73	5.31	13.0	0.5
144	29B	WO_3-SW	17.5	850	20.2	575	2.95	5.73	13.3	0.5
154	29F	WO_3-SW	3.4	1100	14.9	575	0.22	0.44	13.3	0.1
152	29I	WO_3-SW	12.5	1100	16.5	576	0.86	1.61	13.2	0.1
153	29C	WO_3-SW	26.7	1100	19.3	574	0.61	1.21	13.4	0.1

E. Shell WO_3-NiO Catalyst

16	1B	WO_3	60.0	1100	39.7	564	0.10	0.20	17.0	0.1
17	1B	WO_3	60.0	1100	39.7	563	0.10	0.20	14.7	0.1

F. Harshaw Co-ThO_2 on Kieselguhr

66	9A	ThO_2	10.0	....	24.6	626	0.16	0.30	9.3	0.1
67	9A	ThO_2	10.0	....	24.6	666	0.14	0.24	7.2	0.1

Meaning of Symbols: *NW*—Sodium Tungstate; *PW*—Phosphotungstic Acid; *SW*—Silicotungstic Acid; *C*—Coprecipitated; *S*—Soaked; *G*—German Hydrogenation Catalyst; *H*—Harshaw Catalyst.

* Promoter is not used in its real sense throughout this paper, for it usually pertains to small percentages of additives. The Al_2O_3, Al_2O_3-gel and SiO_2-gel are catalyst supports and WO_3, MoO_3 and others are undoubtedly the real catalysts.

Table 3.—Effect of Experimental Conditions on Ethanol Yield over Several Catalysts

A. Effect of Varying Temperature and Pressure over the German WO_3—Al_2O_3 Catalyst

Run No.	Catalyst No.	Temp. °F.	Press. lb./sq.in. abs.	Sv. $hr.^{-1}/10^3$ obs.	C_2H_4/H_2O ratio abs.	Ethanol mole obs.	Yield % corr.	C_2H_4 Conv. % obs.	C_2H_4 Conv. corr.	Equil. C_2H_4 conv. %	% C_2H_4 conv. to polymer
23	3A	557	1515	0.76	1.32	0.28	0.22	0.49	0.44	15.4	0.1
24	3A	620	1515	0.77	1.34	1.18	0.92	2.03	1.82	9.6	0.2
49	38	629	1515	1.07	0.94	0.70	0.97	1.42	1.92	9.1	0.2
51	38	656	1515	1.08	0.94	1.36	1.17	2.79	2.74	7.6	0.5
52	38	625	2515	0.93	1.38	0.70	0.92	1.20	1.82	14.3	0.7
50	38	656	2515	1.01	1.03	1.15	1.17	2.19	2.32	11.7	1.0
B. Effect of Varying Space Velocity over WO_3—Al_2O_3-gel Catalysts											
107	158	626	1515	0.33	0.86	2.31	*2.33	4.90	*4.55	9.1	1.5
103	158	624	1515	1.50	1.33	1.91	*1.85	3.29	*3.64	9.3	0.7
106	158	624	1515	2.55	1.21	1.30	*1.31	2.31	*2.59	9.3	0.5
104	158	618	1515	3.10	0.32	0.75	*1.02	3.04	*2.02	9.8	0.4
105	158	619	1515	4.72	0.42	0.71	*0.85	2.39	*1.69	9.6	0.3

* Corrected for mole ratio only.

C. Effect of Varying Temperature and Total Pressure over WO_3—SiO_2-gel Catalysts

267	29K	508	225	1.50	0.99	0.81	0.75	1.62	1.50	3.6	0.1
233	29K	548	225	1.71	3.96	0.43	0.68	0.49	1.35	2.7	0.1
235	29K	548	225	1.87	3.14	0.46	0.70	0.61	1.39	2.7	0.1
205	29K	471	515	1.58	0.98	1.26	1.33	2.55	2.62	11.5	0.1
204	29K	511	515	1.80	0.77	1.86	2.03	4.20	3.98	8.4	0.2
202	29K	520	515	1.78	0.77	1.97	2.07	4.30	4.06	6.6	0.2
206	29K	550	515	1.76	0.75	1.64	1.79	3.78	3.52	6.0	0.3
207	29K	583	515	1.64	0.89	1.53	1.64	3.21	3.23	4.6	0.4
201	29K	505	1015	1.92	0.70	1.69	1.88	4.06	3.69	16.3	0.2
200	29K	520	1015	1.75	0.70	2.06	2.12	4.56	4.15	15.0	0.2
199	29K	544	1015	2.16	0.60	2.93	3.41	7.50	6.59	12.0	0.3
198	29K	582	1015	2.16	0.55	1.98	2.37	5.45	4.75	8.8	0.4
190	29J	*442	1515	1.67	0.79	0.12	0.12	0.25	0.25	35.0	0.1
189	29J	490	1515	1.51	0.94	0.54	0.56	1.10	1.11	27.0	0.1
172	29J	520	1515	1.78	0.79	2.04	2.19	4.52	4.28	20.0	0.3
188	29J	530	1515	1.76	0.77	3.30	3.47	7.33	6.70	19.0	0.3
208	29K	545	1515	2.00	0.68	3.30	3.67	7.97	7.08	17.0	0.5
187	29J	578	1515	1.82	0.73	3.25	3.46	7.47	6.69	12.9	0.5
209	29K	583	1515	1.96	0.70	3.16	3.51	7.46	6.78	12.1	0.5
210	29K	583	2025	1.74	0.88	3.74	4.07	7.72	7.81	15.6	0.7

* Mixed phase.

D. Effect of Varying Space Velocity over WO_3—SiO_2-gel Catalysts *

211	29K	519	1015	0.36	1.64	....	3.12	....	6.06	15.2	0.3
212	29K	520	1015	1.00	1.02	....	2.90	....	5.63	15.0	0.2
213	29K	519	1015	1.50	1.33	....	2.20	....	4.03	15.2	0.1
214	29K	523	1015	3.16	1.08	....	1.59	....	3.08	14.7	0.1
215	29K	521	1015	5.41	0.93	....	0.79	....	1.57	14.9	0.1
155	29J	579	1515	0.19	0.80	....	2.72	....	5.80	12.8	1.3
170	29J	579	1515	0.35	1.02	....	3.58	....	6.91	12.8	1.3
157	29J	578	1515	0.61	1.19	....	3.37	....	6.52	13.0	1.0
161	29J	579	1515	1.03	0.50	....	3.28	....	6.35	12.8	0.7
156	29J	578	1515	1.54	1.00	....	3.41	....	6.59	12.9	0.5
160	29J	576	1515	2.27	0.54	....	3.23	....	6.26	13.2	0.5
166	29J	579	1515	3.16	0.98	....	2.91	....	5.66	12.8	0.3
176	29J	575	1515	3.97	1.24	....	2.28	....	4.45	13.3	0.2
174	29J	575	1515	5.36	0.70	....	1.66	....	3.26	13.3	0.2
177	29J	578	1515	9.85	1.00	....	0.83	....	1.65	12.9	0.1
175	29J	578	1515	11.5	0.88	....	0.65	....	1.29	12.9	0.1

* Corrected for mole ratio only.

E. Effect of C_2H_4—H_2O Ratio on Ethanol Yield over WO_3—SiO_2-gel Catalysts *

233	29K	548	225	1.71	3.96	....	0.44	....	....	....	....
235	29K	548	225	1.87	3.14	....	0.52	....	....	....	....
229	29K	546	285	1.78	1.80	....	0.87	....	....	....	....
250	29L	550	305	0.96	1.26	....	1.12	....	....	....	....
239	29K	546	255	0.75	0.55	....	0.93	....	....	....	....
252	29L	548	265	1.00	0.23	....	0.55	....	....	....	....
240	29K	546	255	2.73	0.12	....	0.35	....	....	....	....
255	29L	546	515	1.40	2.16	....	1.60	....	....	....	....
226	29K	546	515	1.08	1.63	....	1.55	....	....	....	....
260	29L	551	515	1.39	0.98	....	1.88	....	....	....	....
227	29L	549	515	2.02	0.52	....	1.64	....	....	....	....
258	29L	548	1515	1.29	1.70	....	3.34	....	....	....	....
259	29L	550	1515	1.81	1.32	....	3.71	....	....	....	....
208	29K	545	1515	2.00	0.68	....	3.53	....	....	....	....

* Ethanol yield corrected to standard space velocity.

of WO_3 content. The WO_3—Al_2O_3 catalysts were considerably less active, particularly at the lower temperatures that would be commercially preferred. The several catalysts without WO_3 gave still less conversion.

Figure 5 shows that the optimum WO_3 content was about 15 to 18% and that high activation temperatures decreased the activity. Ethanol yields per unit of catalyst bulk volume were the same for catalysts prepared from desiccant and intermediate density silica gels, even though the desiccant gel catalysts were 50% denser and held 50% more WO_3. About 5% of the reacting ethylene polymerized over these catalysts at 575° F., 1500 lb./sq.in., and standard conditions, which was considerably less than over the alumina supported catalysts. Polymerization always decreased when steam to ethylene ratio was increased, as expected, and on reduction of the temperature. No side reactions other than ethylene polymerization were ever detected in appreciable quantities.

No long-term tests were carried out to determine economical catalyst life and reactivation possibilities, but catalyst 29L-1 was used for 46 hr. at 550° F. without detectable change in its activity. Other runs showed some fall-off in activity.

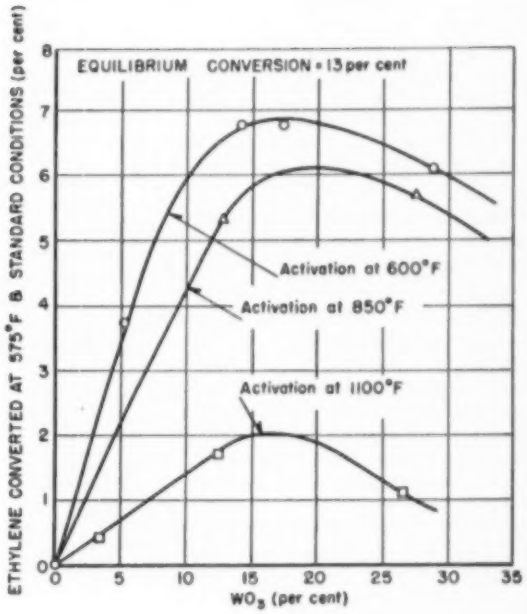

Fig. 5. Effect of increasing percentage WO_3 and the activation temperature in WO_3—SiO_2 catalyst 29.

B. EFFECT OF OPERATING CONDITIONS ON YIELD

Table 3 summarizes the runs carried out under conditions other than the standard ones. It is apparent from Figure 4 that each catalyst had an optimum practical temperature range. It would be uneconomical to exceed some 560° F. with the WO_3—SiO_2-gel catalysts or 650° F. with the WO_3—Al_2O_3 catalysts.

Increasing the pressure at constant steam to ethylene ratios improved the ethanol yield rapidly at the start, but later it became asymptotic to a maximum, as shown in Figure 6. Since higher pressures increased polymerization with all of the catalysts, there would seem to be little practical advantage in pushing the pressure as close to the dew point as possible.

Figure 7 shows that when the space velocity was decreased the yield always increased. However, at the higher pressures, which favor polymer formation, the yield tended to level off considerably below the predicted equilibrium yield.

Steam to ethylene mole ratios greater than one were found advantageous for all catalysts because of the decrease in ethylene polymerization. However, care must be taken to prevent the ratio becoming large enough to produce condensation when the WO_3—SiO_2-gel catalysts are used because they lose activity permanently in the mixed phase. Simi-

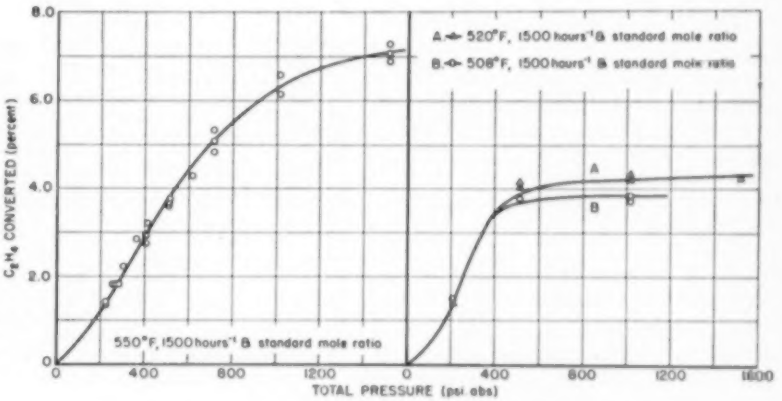

Fig. 6. Effect of pressure on ethylene conversion over WO_3—SiO_2 catalyst 29.

Table 4.—Experimental Determination of the Equilibrium Constant at 554° F. from Dehydration Runs over WO_3–SiO_2-gel Catalyst 29K

Run No.	Catalyst No.	Pressure—lb./sq.in. Total	Ethanol	Temp. ° F.	S_v hr.$^{-1}$	% Ethanol conv. to C_2H_4	% Ethanol conv. to $(C_2H_5)_2O$	$K_r \times 10^2$ Obs.	$K_r \times 10^2$ Calc.
224	29K	1080	245	555	73	96.3	0.0	3.4	3.40
223	29K	1070	440	554	300	94.6	0.0	3.4	3.45
222	29K	1040	530	553	580	90.5	2.9	3.8	3.50
220	29K	1040	705	555	1600	66.0	18.2	11.5	3.40

lar tests with the other catalysts were not conducted. A summary of the effect of experimental conditions on ethanol yield over several catalysts is given in Table 4.

Some runs were carried out on the WO_3—SiO_2 catalysts under conditions that would cause condensation of liquid phase. Subsequent standard runs always showed that the catalysts had permanently lost activity.

C. EXPERIMENTAL DETERMINATION OF THE EQUILIBRIUM CONSTANT FOR THE REVERSE REACTION

When it was observed in the space velocity series with WO_3—SiO_2-gel catalysts, Figure 7, that in some cases the ethylene conversion leveled off below the calculated equilibrium, dehydration runs were carried out with alcohol over the same catalyst to check the equilibrium from the other side. One hundred per cent ethanol with nitrogen as a carrier was passed over catalyst 29K at 550° F. at about 1050 lb./sq.in. total pressure and space velocities varying from 1600 down to 70 $hr.^{-1}$ The results, given in Table 4 and Figure 1, check Equation (1) closely. No detectable quantity of ethylene polymer was formed in these runs. The results are interesting kinetically, for Table 4 shows that large quantities of ethyl ether formed at the higher space velocities, though none remained in the exit stream at low space velocities. Apparently ether is an intermediate unstable product in the reverse reaction, which is probably second order rather than first order. This finding contrasts with that of Sliepcevich and Brown (*16*), who found only negligible amounts of ether when dehydrating butanol-1.

Kinetics of Hydration of Ethylene Over WO_3–SiO_2-gel Catalysts

The experimental procedure was planned to establish the rate equation from integral conversion data at essentially isothermal conditions over WO_3—SiO_2-gel catalyst No. 29. The fugacity of each reactant was varied from 50 to 1000 lb./sq.in. at four temperatures up to 580° F. Low temperatures and fugacities were chosen, so that polymer formation would not be significant.

Figure 8 shows that neither reactant is adsorbed preferentially to the other, since the reaction rate increases in like fashion when the fugacity of either reactant is increased while the other is constant. This fact and the S-shaped curves* of Figure 6 (*20*) suggest either of the two following situations: (*1*) both reactants are equally and slightly adsorbed, with no retardation by products, or (*2*) both reactants are equally and moderately adsorbed, with retardation by product adsorption.

(1) SURFACE REACTION ASSUMED CONTROLLING

The first step in the analysis was to integrate the corresponding Equations (10) and (12), with suitable simplifying assumptions, over the extent of the reaction. The reaction rate r is related to the fugacity f_R of the ethanol by the material balance $rdW = FdN_R$, which approximately $= F(N_R/f_R)_{final}df_R$. Separating the variables results in

$$\int_o^W \frac{dW}{F} = \frac{W}{F} = \left(\frac{N_R}{f_R}\right)_{final} \int_o^{(f_R)_{final}} \frac{df_R}{r} \qquad (16)$$

Equation (16) is integrated by substituting r from Equation (10) and holding f_A and f_B constant at their average values, f_{Aa} and f_{Ba}, since they do not change much during a run. Also, f_RK_R is neglected because f_R is small compared with f_A and f_B, and K_R would be expected to be small compared with K_A and K_B. Finally, K_A and K_B are taken as equal from Figure 8. The integration yields:

$$\frac{WEZf_{R,f}}{FN_{R,f}K_f(1/K_A + f_{Aa} + f_{Ba})^2} = -2.3\log_{10}\left(1 - \frac{f_{R,f}}{(K_f f_{Aa} f_{Ba})}\right) \qquad (17)$$

Equation (17) can be simplified by letting

$$U = 2.3\log_{10}(1 - f_{Rf}/K_f f_{Aa} f_{Ba}) \qquad (18)$$

and rearranging to

$$(f_{Aa} + f_{Ba}) = \left(\frac{Wf_{Rf}E}{FN_{Rf}K_fU}\right)^{1/2}(Z)^{1/2} - \left(\frac{1}{K_A}\right) \qquad (19)$$

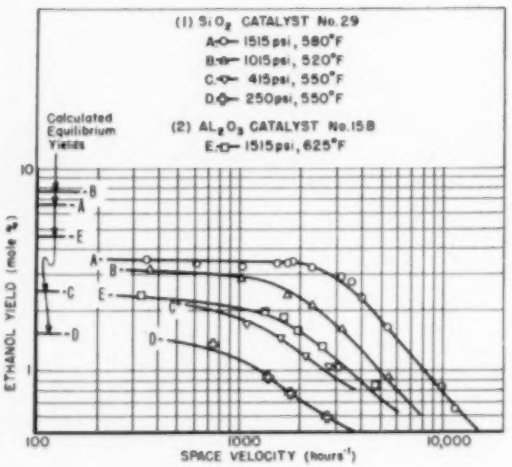

Fig. 7. Effect of space velocity on ethanol yield over WO_3—SiO_2 and WO_3—Al_2O_3 catalysts corrected to H_2O/C_2H_4 mole ratio = 1.

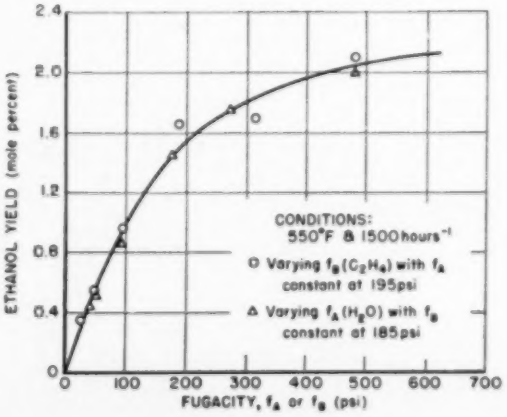

Fig. 8. Effect on reaction rate over WO_3—SiO_2 catalyst 29 of varying the fugacity of either reactant, independently.

* Actually, initial reaction rate r_o should be employed in this plot. However, the same conclusions can be drawn from the average rate, or the conversion, as plotted in Figure 6. Apparently, one of the reactants does not dissociate before reacting because Figure 8 is the same for both reactants and because Figure 6 does not show a decrease in conversion after the first high value.

Since all the quantities in the first square root term are known, it can be plotted against $(f_{Aa}+f_{Ba})$ for runs at the same temperature. If a substantially straight line results, this is a possible mechanism for the reaction, and Z can be determined from the slope and K_A from the intercept of the best straight line through the points.

(2) ADSORPTION OF PRODUCT CONTROLLING

The same assumptions were made here as in the preceding case, except that K_R was not neglected. The final form of the expression is

$$K_A(f_{Aa}+f_{Ba})+K_R(K_f f_{Aa} f_{Ba}) = \left(\frac{f_{Rf}WEZ_R}{FN_{Rf}U}-1\right) \qquad (20)$$

All of the quantities on the right-hand side can be evaluated except Z_R. If this mechanism is obeyed, K_A, K_R, and Z_R can be computed from any group of three runs at constant temperature by simultaneous solution, or from more than three by the method of least squares.

Reaction Mechanism and Rate Constants

The two rate equations were quantitatively evaluated by means of the experimental results at 550° F. To get their best values, the constants in each equation were determined by the method of least squares. The better equation for the data was established as that for which the sum of the squares of the deviations between the least squares and the actual values of $(f_{Aa}+f_{Ba})$ is less, provided that the values of the rate and equilibrium constants are reasonable.

In Table 5 are listed the values required in evaluating the product adsorption control mechanism at 550° F. The most probable values of the constants in Equation (20) were found to be: $K_A = -0.00213$, $K_R = 0.00128$, and $Z_R = -0.881 \times 10^{-6}$, which tends to throw out this mechanism immediately on account of the negative signs. The deviation, D, for any point was computed by

$$D = -\frac{1}{K_A} - \frac{K_R}{K_A}(Kf_{Aa}f_{Ba}) + \frac{Z_R}{K_A}\left(\frac{Wf_{Rf}E}{FN_{Rf}U}\right) - f_{Aa} - f_{Ba} \qquad (21)$$

Table 7.—Least Squares Values of the Adsorption Equilibrium and Rate Constants for the Direct Hydration of Ethylene. Surface Reaction Assumed Controlling and Adsorption Equilibrium Constants of Ethylene and of Steam Assumed Equal

Temperature (° F.)	K_A and K_B (× 100)	Z (× 100)
508	1.56	0.430
520	0.889	0.665
550	0.208	1.72
580	0.114	2.33

Table 5.—Rate Data for WO_3-SiO_2 Catalysts in Terms of Product Adsorption Controlling (Equation 20) at 550° F.

Run No.	Catalyst No.	f_{Aa} lb./sq.in.	f_{Ba} lb./sq.in.	f_{Rf} lb./sq.in.	S_r $hr.^{-1}/10^5$	K_f × 10^5	$(f_{Aa}+f_{Ba})$ lb./sq.in.	$(Kf_{Aa}f_{Ba})$	$\left(\frac{Wf_{Rf}E}{FN_{Rf}U}\right)$ × 10^{-6}
259	29L	475	830	36.6	1.81	3.57	1305	1420	66.0
208	29K	660	585	29.3	2.00	3.57	1245	1400	60.2
263	29L	435	470	25.4	1.53	3.57	905	730	45.2
199	29K	520	370	20.8	2.16	3.57	890	695	33.5
262	29L	555	315	17.7	2.20	3.57	870	630	38.2
231	29K	495	185	11.5	1.71	3.57	680	328	30.7
247	29L	195	475	13.2	1.86	3.57	680	336	25.4
248	29L	195	480	12.9	1.84	3.57	675	334	25.8
249	29L	170	410	10.2	1.71	3.57	580	252	22.5
241	29K	259	222	6.40	1.84	3.57	480	205	19.8
244	29L	276	200	8.10	1.75	3.57	475	198	19.7
228	29K	278	198	8.00	1.76	3.57	475	199	19.7
245	29L	195	187	5.73	1.60	3.57	380	132	16.8
238	29K	217	164	3.56	2.11	3.57	380	127	15.5
237	29K	255	124	2.87	2.75	3.57	380	114	13.3
251	29L	195	95	2.85	1.68	3.57	290	66	12.4
240	29K	214	27	0.48	2.75	3.57	240	21	9.8
229	29K	95	181	2.32	1.78	3.57	275	61	12.0
235	29K	52	169	0.99	1.87	3.57	220	31	10.4
233	29K	43	179	0.89	1.71	3.57	220	27	11.5

Table 6.—Rate Data for WO_3-SiO_2 Catalysts in Terms of Surface Reaction Controlling (Equation 19)

A. Rate equation parameters at 580° F.

Run No.	Catalyst No.	f_{Aa} lb./sq.in.	f_{Ba} lb./sq.in.	f_{Rf} lb./sq.in.	S_r $(hr.^{-1})/10^5$	FN_{Rf}/W × 10^5	K_f × 10^5	$(f_{Aa}+f_{Ba})$ lb./sq.in.	$\frac{(Wf_{Rf}E/FN_{Rf}K_fU)^{1/2}}{\times 10^{-6}}$
210	29K	720	905	43.0	1.74	4.84	2.80	1625	1.69
196	29J	660	610	29.5	1.80	4.28	2.80	1270	1.41
195	29K	650	630	32.0	1.92	4.76	2.80	1280	1.40
171	29J	640	640	30.3	1.80	4.44	2.80	1280	1.39
167	29J	630	650	31.0	1.83	4.61	2.80	1280	1.39
165	29J	585	715	24.9	1.73	3.51	2.80	1300	1.42
159	29J	630	660	30.4	1.83	4.53	2.80	1290	1.40
198	29K	545	345	14.6	2.16	3.21	2.80	890	1.17
197	29J	460	445	14.4	1.96	2.98	2.80	905	1.19
207	29K	246	238	6.6	1.64	1.90	2.80	485	0.85

B. Rate equation parameters at 550° F.

259	29L	475	830	36.0	1.81	5.61	3.57	1305	1.36
208	29K	660	585	29.3	2.00	4.99	3.57	1245	1.30
263	29L	435	470	25.4	1.53	4.07	3.57	905	1.12
199	29K	520	370	20.8	2.16	4.73	3.57	890	0.97
262	29L	555	315	17.7	2.20	4.11	3.57	870	1.03
231	29K	495	185	11.5	1.71	2.54	3.57	680	0.92
247	29L	195	475	13.2	1.86	3.26	3.57	680	0.84
248	29L	195	480	12.9	1.84	3.24	3.57	675	0.85
249	29L	170	410	10.2	1.71	2.73	3.57	580	0.80
241	29K	259	222	6.40	1.84	2.04	3.57	480	0.74
244	29L	276	200	8.10	1.75	2.50	3.57	475	0.74
228	29K	278	198	8.00	1.76	2.47	3.57	475	0.74
245	29L	195	187	5.73	1.60	2.00	3.57	380	0.68
238	29K	217	164	3.56	2.11	1.74	3.57	380	0.66
237	29K	255	124	2.87	2.75	1.68	3.57	380	0.62
251	29L	195	95	2.85	1.68	1.34	3.57	290	0.59
240	29K	214	27	0.48	2.75	0.42	3.57	240	0.53
229	29K	95	181	2.32	1.78	1.22	3.57	275	0.58
235	29K	52	169	0.99	1.87	0.66	3.57	220	0.54
233	29K	43	179	0.89	1.71	0.55	3.57	220	0.57

C. Rate equation parameters at 520° F.

172	29J	480	800	16.0	1.78	2.85	4.75	1280	1.71
213	29K	455	420	9.2	1.72	1.83	4.75	875	1.27
200	29K	320	580	13.6	1.75	2.86	4.75	900	1.23
216	29K	340	560	6.0	2.29	1.60	4.75	900	1.18
202	29K	262	219	7.6	1.78	2.34	4.75	481	0.74

D. Rate equation parameters at 508° F.

201	29K	320	580	11.0	1.92	2.47	5.35	900	1.32
264	29L	400	480	9.0	1.92	2.00	5.35	880	1.57
204	29K	195	285	7.8	1.80	2.53	5.35	480	0.69
265	29L	235	245	9.0	1.09	1.76	5.35	480	0.90
267	29L	102	107	1.6	1.50	0.93	5.35	209	0.54

The value of $(\Sigma D^2)/n$ was obtained as 50,600.

In Table 6 the values used in evaluating the surface reaction control mechanism for all of the temperatures and in Table 7 the least squares values of the constants are given. D was computed at 550° F. by

$$D = -\frac{1}{K_A} + \left(\frac{ZWf_{Rf}E}{FN_{Rf}K_fU}\right)^{1/2} - f_{Aa} - f_{Ba} \qquad (22)$$

The value found for $(\Sigma D^2)/n$ was 1,460. The much smaller value for this mechanism is particularly noteworthy in that only two instead of three assignable constants are available, K_A and K_B having been set equal.

It is thus evident that the surface reaction controls the hydration of ethylene under these conditions. Added corroborative evidence is the good agreement shown in Figure 9 between this mechanism and the data for the other temperatures.

The apparent energy of activation, E^a in the Arrhenius equation:

$$Z = A^* e^{-E^a/RT} \qquad (23)$$

was obtained by the plot of Figure 10. An apparent energy of activation of approximately 30 k cal./g. mole was obtained from the slope of the best straight line. The equilibrium adsorption constants are also shown in Figure 10 for comparison.

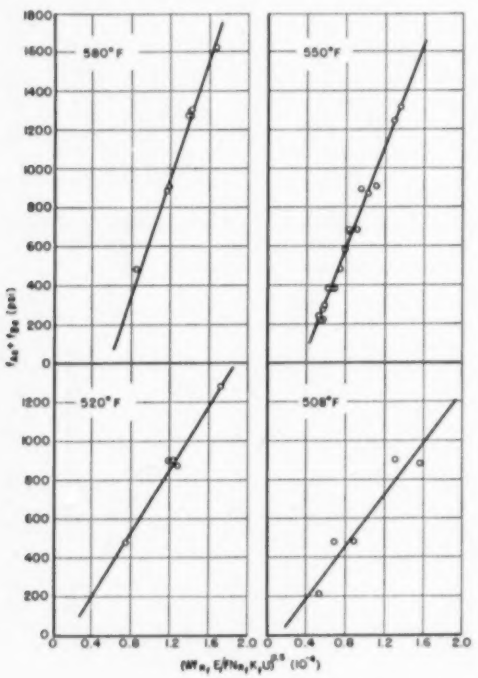

Fig. 9. Rate data correlation with the surface reaction equation.

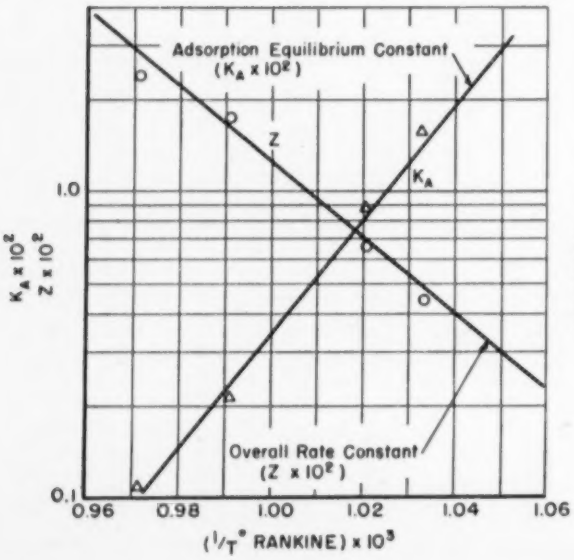

Fig. 10. Effect of temperature on the over-all rate constant and the adsorption equilibrium constant for the surface reaction.

Precision of Kinetic Results

When Equation (19) is rewritten in the form

$$Z = \left[\frac{\left((f_{Aa}+f_{Ba})^2 + \frac{1}{K_A{}^2}\right)FN_{Rf}K_fU}{Wf_{Rf}E}\right] \qquad (24)$$

and the probable error of $(f_{Aa}+f_{Ba})$ at ±2%, of FN_{Rf} at ±3%, of E at ±2%, of f_{Rf} at ±4%, and of U at ±2% is estimated, the maximum likely error is estimated to be $2\times2+3+2+4+2=15\%$. The probable error is considerably smaller, as suggested in Figure 9 by the mutual agreement among the points.

Discussion of Results

Apparently very specific catalysts are required for the efficient hydration of ethylene in the vapor phase, for only WO_3—SiO_2-gel prepared from the heteropolyacids produced ethanol in such quantities as to be of commercial interest. Ethylene conversions as high as 7.8% (half of equilibrium) were obtained at roughly optimum conditions of 1 — 1 mole ratio, 583° F., and 2,000 lb./sq.in. (run 210). The activity of WO_3—SiO_2-gel catalyst is seen to be affected by activation temperature and its performance impaired by formation of liquid phase. The loss in activity above 800° F. is attributed to sintering and indicates that some fundamental change has taken place in the catalyst.

This decreased activity above 800° F. is particularly significant because it limits the range of conditions that may be employed with these catalysts for the hydration of ethylene. Dodge (*14*) recommended the use of steam to ethylene ratios as great as 10 over his alumina catalysts to decrease polymerization, and high pressures to increase conversion. Such high ratios require higher temperatures, however, to avoid condensation, and seem uneconomical and unnecessary with the best WO_3—SiO_2-gel catalysts.

The rate mechanisms assumed in analyzing the results obtained with the standard catalyst 29J-M did not include any diffusional resistance. The good correlation of these results by the simple mechanism of surface reaction control is strong evidence that diffusion both inside and outside the particles was not a factor. Furthermore, preliminary

runs with the same space velocity, catalyst, bed cross section, and other conditions, but a threefold change in bed depth and therefore total flow, yielded the same conversion. This is direct evidence that there was no significant diffusional resistance outside the particles.

It is of interest to note, however, that run 140, with fine-pored desiccant gel as a support, and 143, with the intermediate density gel, yielded at identical conditions the same conversion for the same volume of catalyst rather than for the same weight. This might be interpreted to indicate that diffusion into the pores is an important factor. Additional runs with larger particle sizes would have clarified the point. Other explanations are possible, however, such as differences in the specific activity per unit area or in the facility of impregnation of the support. Thus it is believed that Equation (19) with Table 7 and Figure 1 will correctly give the hydration rate for at least somewhat larger and all smaller particles of catalyst 29J-M.

Although Tanner reported high ethanol yields over MoO_3—SiO_2 catalysts from phosphomolybdic acid, they were inactive in these studies. The activity of his catalysts may have been due to the presence of a larger percentage of H_3PO_4, for phosphoric acid alone on SiO_2 has been reported to be an active catalyst. The ratio of H_3PO_4 to MoO_3 was 2.2 in Tanner's catalyst and only 0.1 in the present ones. Consequently, it is not definitely known whether the heteropolyacids as a group or only the tungsten-containing acids produce an active catalyst for the hydration of ethylene. This might be settled by testing metals other than W and Mo in the form of the heteropolyacids.

Figure 10 shows that the adsorption equilibrium constant for the reactants decreases more rapidly than the velocity constant increases with rising temperature. This probably brought about the retardation in the reaction rate at higher temperatures observed in Figure 4 and is characteristic of many vapor phase reactions catalyzed by solid surfaces. At low temperatures an increase in temperature causes an increase in reaction rate owing to increased activation, whereas at higher temperatures the reaction is slowed because of decreased adsorption of the reactants. Hougen and Watson (*10*) observed this phenomenon when hydrogenating mixed isooctenes in the vapor phase on a supported nickel catalyst. The same behavior was reported by Akers and White (*1*) in the methane synthesis over a nickel catalyst.

The value obtained for the apparent energy of activation should be regarded as an approximation, for it was obtained with the assumption that neither it nor the activity of the catalyst varied with temperature. The failure of all the points in Figure 9 to lie on a straight line could be due to this.

Acknowledgment

The authors are happy to acknowledge the interest of the Research and Development Department of the Phillips Petroleum Co., which sponsored this work and has permitted its publication. Advice and assistance were received from Professors W. A. Patrick and B. L. Harris. Catalyst samples from the Harshaw Chemical Co. are acknowledged.

Notation

A^* = frequency factor in Arrhenius equation

a = average value, subscript

A = H_2O

B = C_2H_4

C_A, C_B, C_R = surface molal concentrations of A, B and R respectively, moles per unit catalyst mass

C_L = number of vacant molal active sites per unit catalyst mass

D = deviation of an observation from the equation

E = catalyst fouling factor

E^* = apparent energy of activation

f = fugacity in lb./sq.in. (as subscript to f_R and N_R refers to outlet ethanol)

F = total feed rate at inlet, g. moles/hr.

g = gas phase

k = surface reaction velocity constant

K_A, K_B, K_R = adsorption equilibrium constants of components A, B and R respectively

K' = surface reaction equilibrium constant = $K_f K_R / K_A K_B$

K_f = thermodynamic equilibrium constant, $f_{C_2H_5OH} / (f_{C_2H_4} \times f_{H_2O})$

L = number of molal active sites per unit catalyst mass

n = number of observations

N_R = gram moles of ethanol formed/g. mole of total feed

P = total pressure, lb./sq.in.

P_A, P_B, P_R = partial pressure of components A, B and R respectively

R = C_2H_5OH

R^* = C_2H_4/H_2O mole ratio

r = net rate of reaction, moles R/hr./g. catalyst

r_1 = rate of forward bimolecular surface reaction

r_2 = rate of reverse monomolecular surface reaction

S_v = space velocity, cc. at S.T.P. of total feed/cc. catalyst/hr. = $hr.^{-1}$

s = number of dual active sites per catalyst site

T = absolute temperature

$U = \ln\left(1 - \dfrac{f_{RF}}{K_f f_{Ae} f_{Be}}\right)$

W = mass of catalyst, g.

Z = over-all rate constant for surface reaction = ksL

Z_A = over-all rate constant for adsorption of A controlling = $k_A L$

Z_B = over-all rate constant for adsorption of R controlling = $k_B L$

ΔF° = standard free energy change, cal./g.mole

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pulse column variables

Solvent Extraction of Uranyl Nitrate with Tributyl Phosphate in a 3-in.-diam. Pulse Column

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The general performance characteristics of sieve-plate liquid-liquid extraction columns in which the contents are pulsed through the plates are illustrated with data on the solvent extraction of uranyl nitrate with tributyl phosphate in a 3-in.-diam. pulse column. Effects of operating conditions and sieve-plate section design on solvent-extraction effectiveness and capacity are discussed, and the application of the data to columns of larger diameter is indicated. For chemical systems reported a sieve-plate section design termed a "standard cartridge," composed of stainless-steel plates spaced 2 in. apart and perforated with ⅛-in. holes to yield 23% free area, has been found a useful compromise between the conflicting objectives of high throughput capacity and near-optimum extraction effectiveness. With such a column design, extraction effectiveness generally improves as either the pulse amplitude or frequency is increased, optimum performance typically occurring slightly below an amplitude-frequency product which results in flooding the column because of excessive emulsification. The height of a transfer unit or height equivalent to a theoretical stage for pulse columns operating at near-optimum conditions frequently is approximately one third as high as for a conventional packed extraction column. Throughput capacities of the two types of contactors are comparable.

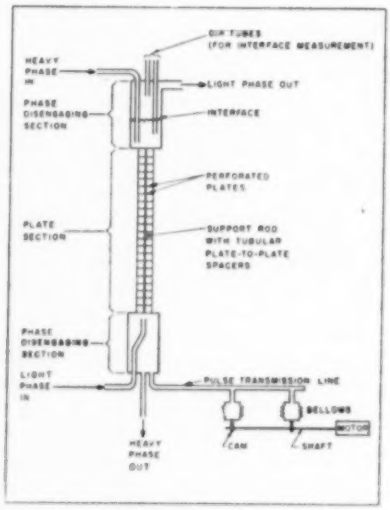

Fig. 1. Schematic sketch of pulse column.

A pulsed perforated-plate column, originally described by Van Dijck (*1*) and perhaps first applied to uranium separation by C. Groot, offers an important, often more than twofold, reduction in column height from the heights needed with a conventional packed column. In such a column an up-and-down pulsing motion is superimposed on the net countercurrent flow of the liquid phases through a series of stationary, spaced horizontal perforated plates.

This article deals with general inferences concerning the performance characteristics of pulsed perforated-plate columns drawn from experimental runs made at Hanford. The general discussion is illustrated with data on the solvent extraction of uranyl nitrate with tributyl phosphate.

SYSTEMS STUDIED

The chemical systems employed in the pulse-column studies from which the illustrative data are drawn (listed in Table 1) represent a variety of countercurrent liquid-liquid extraction systems employing tributyl phosphate (TBP) as a solvent for uranyl nitrate. For convenient reference the systems are designated by numerals, systems in which the TBP is diluted with carbon tetrachloride bearing numbers under 10 and those in which a lighter-than-water hydrocarbon is employed as diluent for the TBP being numbered higher than 10. Extraction-column systems (i.e., those in which the uranium is extracted from an aqueous into an organic phase) are designated by odd numbers, with the next higher even number used to designate the associated stripping-column system (in which the uranium is stripped back into an aqueous phase).

EQUIPMENT

A 3-in.-diam. glass pulse column was used with a perforated-plate section height of approximately 9 ft. (except where otherwise noted). The plate-free column end sections were 3 to 4 in. in diam. and of sufficient length (1 to 6 ft.) to allow several minutes of effluent stream holdup time for phase disengagement. A pulse of variable amplitude and frequency with a sinusoidal displacement-vs.-time characteristic was applied by means of reciprocating stainless-steel bellows or a reciprocating piston. The pulse was usually transmitted from the pulse generator to the column contents through a separate pipeline filled with stagnant liquid (usually the heavy-phase process solution), but pulse transmission through the light-phase influent line was sometimes employed. The interface level was controlled at will above or below the plate section by air-bubbler-type differential-pressure instruments controlling a Hammel-Dahl air-operated flow-control valve on the heavy-phase effluent line.

A schematic sketch of a pulse column is presented as Figure 1. The various perforated-plate designs employed in connection with the illustrative data are listed in Table 2. For convenient reference the several designs are identified by capital-letter symbols, with numerical subscripts used to indicate construction materials other than stainless steel. The perforated plates were held apart in the column by tubular (usually ⅜-in. O.D.) stainless-steel spacers strung on an axial stainless-steel rod.

General Performance Characteristics of Pulse Columns

Three distinct types of phase-dispersion behavior have been observed in pulse columns as a function of the throughput rate and the pulsing conditions (frequency at any given pulse amplitude), as indicated in Figure 2.

MIXER-SETTLER-TYPE OPERATION

The mixer-settler type operation (Figure 3), occurring at low through-

Table 1.—Chemical Flow Sheets

System	Diluent	Vol. % TBP	Direction of U transfer	Aqueous influent†	Organic influent†	A/O
1	CCl_4	30	Aqueous to organic	0.8 $UO_2(NO_3)_2$ 2.4 HNO_3 Sp.gr. 1.35	Sp.gr. 1.4	0.5
2	CCl_4	30	Organic to aqueous	0.03 HNO_3 Sp.gr. 1.0	0.4 $UO_2(NO_3)_2$ 0.2 HNO_3 Sp.gr. 1.5	1.75
3	CCl_4	30	A → O	0.001 $UO_2(NO_3)_2$ 5.5 HNO_3 Sp.gr. 1.2	Sp.gr. 1.4	4.5
4	CCl_4	30	O → A	0.03 HNO_3 Sp.gr. 1.0	0.005 $UO_2(NO_3)_2$ 0.03 HNO_3 Sp.gr. 1.4	0.5
5	CCl_4	15	A → O	0.02 $UO_2(NO_3)_2$ 4 HNO_3 1.3 metal nitrates Sp.gr. 1.3	Sp.gr. 1.5	0.5
6	CCl_4	15	O → A	0.03 HNO_3 Sp.gr. 1.0	0.04 $UO_2(NO_3)_2$ 0.2 HNO_3 Sp.gr. 1.5	0.7
11	Hydrocarbon*	30	A → O	0.8 $UO_2(NO_3)_2$ 2.4 HNO_3 Sp.gr. 1.35	Sp.gr. 0.84	0.5
12	Hydrocarbon*	30	O → A	0.3 HNO_3 Sp.gr. 1.0	0.4 $UO_2(NO_3)_2$ 0.2 HNO_3 Sp.gr. 0.97	1.75
17	Hydrocarbon*	12.5	A → O	0.18 $UO_2(NO_3)_2$ 3.3 Na salts 2.6 HNO_3 Sp.gr. 1.3	Sp.gr. 0.81	0.6
18	Hydrocarbon*	12.5	O → A	0.01 HNO_3 Sp.gr. 1.0	0.11 $UO_2(NO_3)_2$ 0.1 HNO_3 Sp.gr. 0.85	0.8

* Shell Deodorized Spray Base, a refined kerosene-type hydrocarbon with a specific gravity of approximately 0.8.

† Solute concentrations are given as molarities.

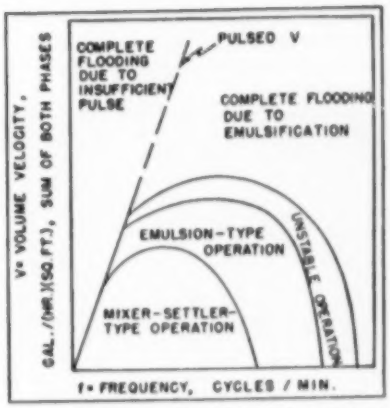
COMPLETE FLOODING DUE TO INSUFFICIENT PULSE
PULSED V
COMPLETE FLOODING DUE TO EMULSIFICATION
EMULSION-TYPE OPERATION
UNSTABLE OPERATION
MIXER-SETTLER-TYPE OPERATION
V* VOLUME VELOCITY, GAL./(HR.)(SQ FT.), SUM OF BOTH PHASES
f* FREQUENCY, CYCLES / MIN.

Fig. 2. Three types of pulse column operation.

put rates and frequencies, is characterized by the separation of the light and heavy phases into discrete, clear layers in the interplate space during the quiescent portions of the pulse cycle. During the upward portion of the pulse movement the light phase initially resting under the sieve plate is forced up through the perforations and rises in fairly large globules through the heavy-phase layer above the plate (typically ⅛-in. to ¼-in.-diam. globules for ⅛-in.-diam. holes in the plates). Similarly the heavy phase descends during the downward movement of the pulse. Under mixer-settler-type phase-dispersion conditions the operation of the pulse column is highly stable but relatively inefficient compared with operation of the same column under emulsion-type conditions.

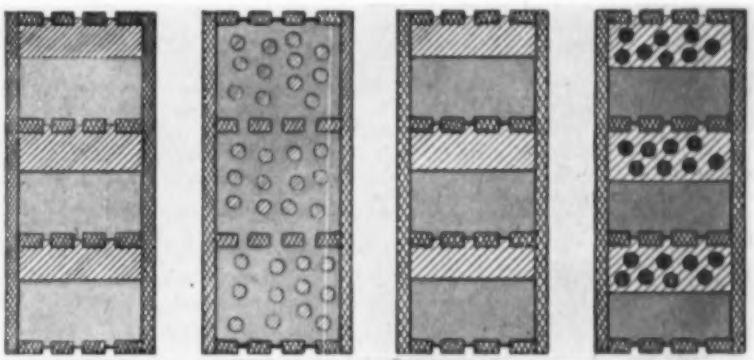

Fig. 3. Mixer-settler-type operation: phase dispersion variation in the course of a pulse cycle. XXXXXX XXXXXX, plates and column wall. //////, light phase. Uniform gray and solid black areas, heavy phase.

Table 2.—Perforated-plate Cartridges

Cartridge	Hole diam., in.	Perforated area, %	Plate spacing, in.	Material
B	0.1875	23	2	Stainless steel
C	0.125	10	2	Stainless steel
E	0.125	23	2	Stainless steel
E_1	0.125	23	2	Fluorothene
E_2	0.125	23	2	Dual *
F	0.125	40	2	Stainless steel
G	0.06	21	2	Stainless steel
J	0.125	23	1.4	Stainless steel
K	0.125	23	3	Stainless steel
L	0.125	23	4	Stainless steel

* Stainless steel with one side coated with Kel-F NW-25 paint (a polytrifluoromonochlorethylene dispersion). Coated side oriented up with heavier-than-water (CCl_4) diluent, down with lighter-than-water (hydrocarbon) diluent.

EMULSION-TYPE OPERATION

The emulsion-type operation (Figure 4), occurring at higher throughput rates and frequencies, is characterized by small drop size (typically about 1/16 in. or less in diam.) and fairly uniform dispersion of the discontinuous phase, with little change in phase dispersion in the

course of the pulse cycle. The intimate interphase contact (high interfacial contact area per unit volume) renders this the most efficient type of operation.

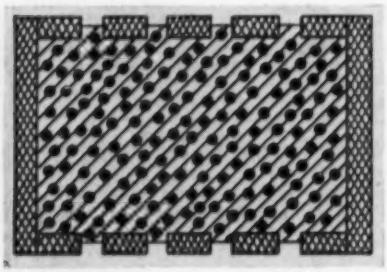

Fig. 4. Emulsion-type operation. XXXXXX, plates and column wall. //////, continuous phase. ■■■■, dispersed phase.

UNSTABLE OPERATION

Unstable operation (Figure 5), occurring at still higher throughput rates and frequencies, is characterized by mixtures of fine and coarse dispersed-phase drops, formation of large, irregular-shaped globs of dispersed phase by coalescence, and periodic reversals of the continuous phase in short sections of column (cyclic local flooding). The efficiency of the column in the unstable operating region is generally poorer than in emulsion-type operation and often fluctuates widely.

As the throughput rate or the frequency is increased still further, beyond the unstable region, complete flooding eventually results. This is defined as the exit of one of the entering streams through the effluent line intended for the other phase.

The changes in phase-dispersion behavior accompanying changes in frequency or throughput rate involve gradual blending of one type of operation into another, rather than abrupt transitions.

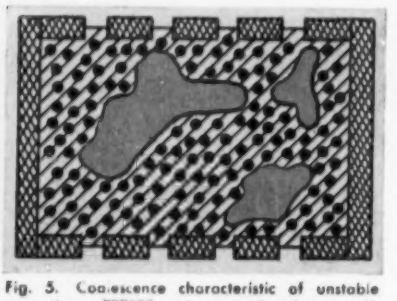

Fig. 5. Coalescence characteristic of unstable operation. XXXXXX, plates and column wall. //////, continuous phase. ■■■■, dispersed phase. Irregular gray masses also indicate dispersed phase.

Main Factors Affecting Performance

Apart from the properties of the liquid-liquid system, the main factors affecting pulse-column performance may be grouped as follows:

(a) Pulse amplitude, frequency, and throughput rate; (b) phase flow ratio, choice of continuous phase, and plate wetting characteristics; (c) plate geometry [hole size, plate spacing, percentage of free (perforated) area, plate-to-wall clearance]; (d) diffusing-component concentration; (e) column diameter. At first glance a methodical study of the dozen variables listed above (making only three runs for each variable in turn, with all others held constant) would appear to require 3^{12} or approximately 530,000 runs. However, some general inferences can be made from the results of the experiments reported.

Preliminary scouting runs served rather rapidly to converge the interest in plate geometries toward a "standard" geometry (cartridge E), which appears to be a practical compromise giving near-optimum all-around performance on a number of chemical systems tried. Although the effects of many of the foregoing variables have been only scouted rather than methodically studied, in some cases more than one variable having been changed simultaneously, conclusions from the over-all program are believed to be of sufficient general interest for presentation at this time.

EFFECTS OF PULSE AMPLITUDE AND FREQUENCY

As indicated by Figure 2, the operation of a pulsed sieve-plate column is markedly different from that of a packed column, in that no measurable countercurrent flow can be obtained in a pulse column (with the sieve-plate designs normally chosen) unless the column contents are pulsed. At low frequencies the capacity of the column is equal to the pulsed volume velocity * and thus increases in proportion to the arithmetic product of the amplitude and the frequency, $a \times f$, or, at constant amplitude, in proportion to the frequency, f. As the frequency increases further, the flooding capacity becomes increasingly lower than the pulsed volume velocity. After passing through a maximum the flooding capacity decreases with further increases in the frequency (or amplitude-frequency product) until above a limiting amplitude-frequency product no countercurrent flow through the column is possible. Figure 6 is a group of plots of experimental data illustrating the relation between the flooding volume velocity and the amplitude-frequency product.

* The *pulsed volume velocity* is defined in units such as gallons pulsed/(hour) (square foot of column cross section) and may be calculated by multiplying the pulse frequency (in cycles/hour) by the pulse displacement in gallons (employing the sum of the "up" plus "down" displacements) and then dividing by the column cross section in square feet. The pulsed volume velocity is directly proportional to both the pulse amplitude and the frequency.

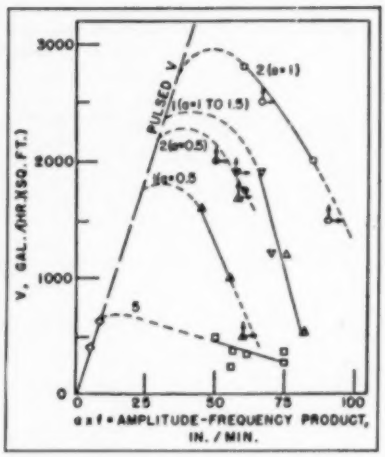

Fig. 6. Flooding characteristics, cartridge E, aqueous phase continuous. ▲, system 1, a = 0.5. △, system 1, a = 1.0. ▽, system 1, a = 1.5. ●, system 2, a = 0.5. ○, system 2, a = 1.0. ◇, system 5, a = 0.05 to 0.1. □, system 5, a = 0.85 to 1.25. †, column operated without flooding at indicated conditions.

In some cases stable emulsion-type operation is observed at amplitude-frequency products (af) and volume velocities (V) quite close (within 10 to 15% or less) to the complete flooding threshold. Such was the case with the CCl_4-diluent systems and stainless-steel perforated-plate cartridge on which Figure 6 is based. In other instances unstable operation occurs over a wide range of throughputs and pulse conditions as complete flooding is approached. Thus Figure 7, representing data on a plastic perforated-plate cartridge used in conjunction with process system 2, indicates cyclic local flooding thresholds occurring at about half the complete flooding volume velocities.

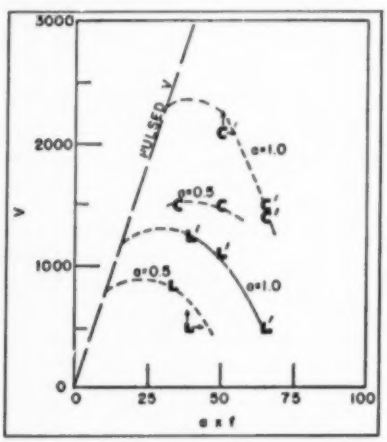

Fig. 7. Complete and local flooding characteristics of system 2 with perforated-plate cartridge E_1. Organic phase continuous. C', complete flooding, a = 1.0. C, complete flooding, a = 0.5. L', cyclic local flooding, a = 1.0. L, cyclic local flooding, a = 0.5.

Within the region of stable operation, H.T.U. values generally decrease sharply (often over threefold) with increasing amplitude-frequency products as a function of the gradual transition from mixer-settler-type to increasingly intimate emulsion-type phase dispersion. On the threshold of unstable operation there is sometimes a slight reversal of the trend to lower H.T.U. values with increasing pulse as a result of incipient coalescence of the dispersed phase. The shapes of the H.T.U.-vs.-amplitude-frequency-product plots vary with the system and plate design. Most frequently the curves are convex downward. Typical plots of H.T.U. as a function of the amplitude-frequency product are presented in Figures 8 to 10.

The amplitude-frequency product represents a useful, simple means of correlating the pulsing conditions with column performance. A more exact analysis of the data, however, indicates the need for two important additional considerations. One of these is that variation of the amplitude has effects not fully accounted for by the corresponding amplitude-frequency product variation. Thus with a 2-in. plate spacing (the spacing most often used) an approximately 1-in. amplitude * is usually optimum, yielding lower minimum H.T.U. values and higher maximum capacities than a 0.5-in. amplitude and slightly lower H.T.U.'s and about the same capacity as a 1.5-in. amplitude (Table 3 and Figures 6 and 7).

The need for another refinement of the amplitude-frequency-product correlation is indicated by the quite general observation that flooding, good emulsion-type operation, and the lowest H.T.U. values occur at lower amplitude-frequency products with a 0.5-in. amplitude than with a 1-in. amplitude. (The data in Figure 6 and Table 3 illustrate this trend.) A more exact correlator for these effects would be an expression of the form af^n where the exponent n would have some value between 1 and 2 (perhaps typically about 1.5) and might not be the same for all systems or for all ranges of the amplitude. Since correlations have not yet been developed which permit calculation of the value of (af) or (af^n) which will cause a given column to flood at any given operating condition, flooding frequencies must be determined empirically. Once the (af) product which causes the column to flood at a given throughput rate has been determined, experience indicates

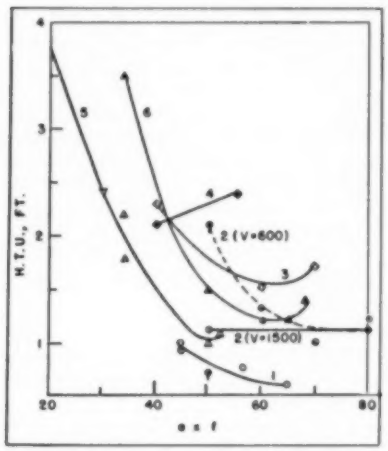

Fig. 8. H.T.U. as a function of amplitude × frequency for CCl_4-diluent systems, with perforated-plate cartridge *E*. Aqueous phase continuous, ○, system 1, $V = 1200$, $a = 0.9$ to 1.4. ⊙, system 1, $V = 1200$, $a = 0.5$. ●, system 2, $V = 600$, $a = 1.0$. ◒, system 2, $V = 600$, $a = 0.5$. ◐, system 2, $V = 1500$, $a = 1.0$. ◑, system 2, $V = 1500$, $a = 0.5$. ◇, system 3, $V = 800$, $a = 1.0$. ◆, system 4, $V = 800$, $a = 1.0$. △, system 5, $V = 400$, $a = 0.8$ to 1.25. ▽, system 5, $V = 400$, $a = 0.4$. ▲, system 6, $V = 400$, $a = 0.8$ to 1.25. Authors advise above diagram should show ▽ at 3.8 — 20; ◒ at 2.1 — 50; ⊙ at 0.7 — 50; ◐ at 1.0 — 70.

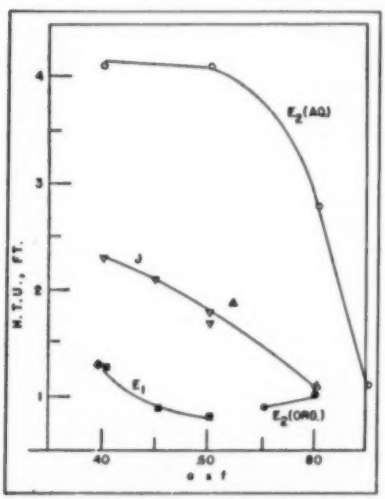

Fig. 9. H.T.U. as a function of amplitude × frequency for system 2 with various perforated-plate cartridges. ○, cartridge E_2, aqueous phase continuous, $V = 1000$, $a = 1.0$. ●, cartridge E_2, organic continuous, $V = 1000$, $a = 1.0$. △, cartridge *J*, aqueous continuous, $V = 1000$, $a = 1.0$. ▽, cartridge *J*, aqueous continuous, $V = 1000$, $a = 0.5$. ■, cartridge E_1, organic continuous, $V = 500$, $a = 1.0$. ◆, cartridge E_1, organic continuous, $V = 500$, $a = 0.5$.

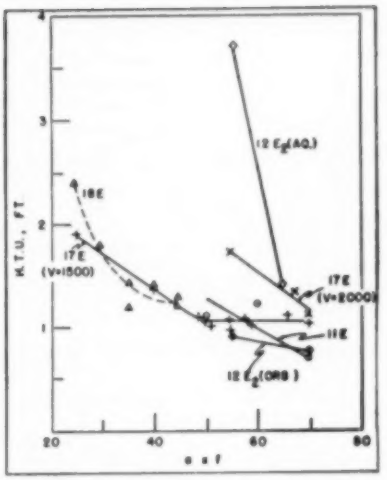

Fig. 10. H.T.U. as a function of amplitude × frequency for hydrocarbon-diluent systems. Aqueous phase continuous, except as noted. ○, system 11, perforated-plate cartridge *E*, $V = 900$, $a = 1.0$. ◇, system 12, cartridge E_2, $V = 1000$, $a = 1.0$. ◆, system 12, cartridge E_2, organic phase continuous, $V = 1000$, $a = 1.0$. +, system 17, cartridge *E*, $V = 1500$, $a = 0.5$ to 1.0. X, system 17, cartridge *E*, $V = 2000$, $a = 0.5$ to 1.0. △, system 18, cartridge *E*, $V = 800$, $a = 0.5$.

* Throughout this article the term *amplitude* is used to indicate the magnitude of the pulse movement of the column contents from one extreme position to the other, i.e., twice the movement from the mean position to an extreme.

Table 3.—Effect of Pulse Amplitude on H.T.U.

System	Perforated-plate cartridge	Continuous phase	V	a	a × f	Approx. % of flooding frequency	H.T.U., ft.
1	*E*	Aqueous	600	0.5	45	70	0.8
				0.5	60	90	0.7
				0.9	57	70	0.6
				1.5	50	70	0.7
				1.5	60	80	0.7
1	*E*	Aqueous	1,200	0.5	45	95	0.9
				0.9	54	75	0.7
				0.9	57	80	0.8
				1.0	70	95	0.6
				1.5	50	75	0.7
2	*E*	Aqueous	1,500	0.5	50	75	1.1
				0.5	60	90	1.2
				1.0	50	55	1.3
				1.0	70	75	1.0
				1.0	80	85	1.2
2	E_1	Organic	500	0.5	40	75 (est'd)	1.2
				1.0	40	60	1.2
				1.0	50	75	0.9
				1.0	60	90	0.8

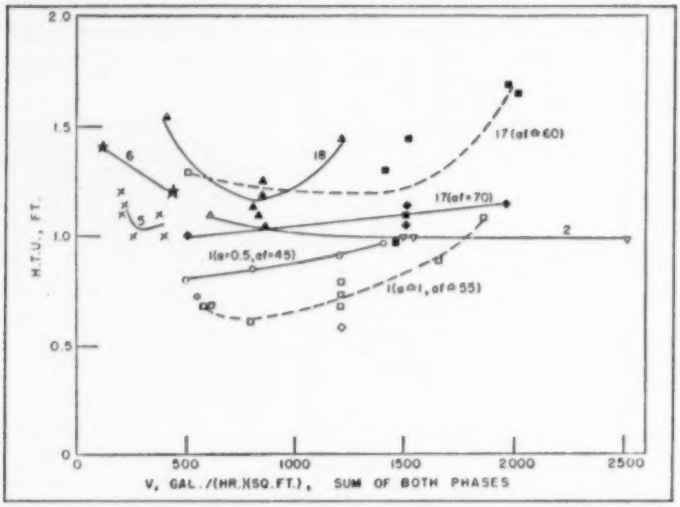

Fig. 11. H.T.U. as a function of the superficial volume velocity, V. Perforated-plate cartridge E. Aqueous phase continuous. ○, system 1, $a = 0.5$, $af = 45$. ⊙, system 1, $a = 0.5$, $af = 60$. □, system 1, $a = 0.9$ to 1.5, $af =$ 50 to 60. ◇, system 1, $a = 1.0$, $af = 70$. ▽, system 2, $a = 1.0$, $af = 70$. △, system 2, $a = 1.0$, $af = 80$. X, system 5, $a = 0.85$ to 1.25, $af = 50$. ★, system 6, $a = 0.8$, $af = 65$. ■, system 17, $a = 1.0$, $af = 55$ to 60. ◆, system 17, $a = 1.0$, $af = 70$. ▲, system 18, $a = 1.0$, $af = 50$.

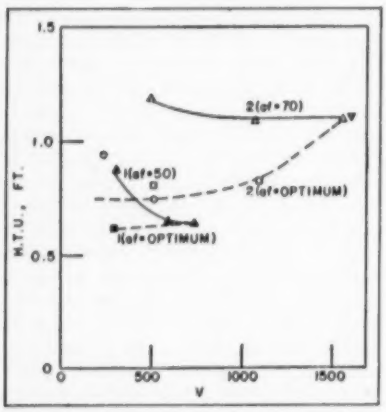

Fig. 12. H.T.U. as a function of the superficial volume velocity, V, at constant af product (solid curves) and at highest stable af for each V (dotted curves). Perforated-plate cartridge G. Aqueous phase continuous. $a = 1$. ▲, system 1, $af = 5$. ■, system 1, $af = 60$. ▽, system 2, $af = 60$. △, system 2, $af = 70$. □, system 2, $af = 80$. ○, system 2, $af = 90$.

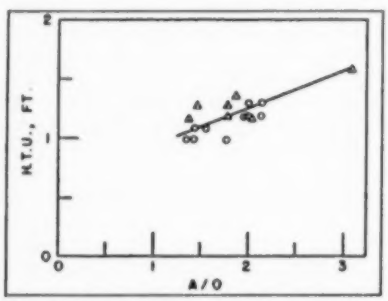

Fig. 13. H.T.U. as a function of the aqueous-to-organic phase flow ratio. System 2. Perforated-plate cartridge E. Aqueous phase continuous. ○, $a = 0.9$ to 1.0, $af = 50$ to 80. △, $a =$ 0.5, $af = 60$.

that the (af) product which will result in near-optimum performance will lie somewhere in the range from 75 to 95% of the flooding (af). If local flooding occurs at a lower (af) than the (af) which produces complete flooding, optimum extraction performance will generally be found at (af) values just below those which cause local flooding. Data illustrating this effect of percentage of flooding frequency on H.T.U. appear in Table 3.

EFFECTS OF THROUGHPUT RATE

Pulse-column H.T.U. values are relatively insensitive to variations in the throughput rate, provided that the applied pulse ensures good emulsion-type phase dispersion. Figure 11 is a plot of H.T.U. values against the throughput rate (expressed in the usual terms of the sum of the superficial volume velocities of the two phases) for a variety of process systems at constant (or approximately constant) pulsing conditions. These curves are generally convex downward and shallow, indicating H.T.U.'s closely approximating the optimum values over a wide (often at least fourfold) range of throughputs, with rising H.T.U. values at high and low rates.

The increase in the constant-pulse H.T.U. values at low throughput rates may usually be circumvented by increasing the frequency or amplitude, taking advantage of the higher flooding amplitude-frequency products at the low throughput rates. This is illustrated in Figure 12, where (with system 1) increasing the frequency from 50 to 60 cycles/min. at a volume velocity of 300 gal./(hr.)(sq.ft.) reduced the H.T.U. from 0.9 to 0.6 ft.

No such expedient is available for flattening the H.T.U.-vs.-throughput curve at the high-rate end; therefore a diameter decrease gained from a column design based on a high superficial flow rate must often be paid for with increased column height or impaired solvent-extraction performance (fewer transfer units in the column). On the other hand, choosing the larger diameter column with the lower superficial flow rate will not necessarily be a preferred alternative because H.T.U. values also increase with column diameter (owing to the "scale-up" factor) and because the larger diameter column may require purchasing a larger, more expensive pulse generator.

EFFECTS OF PHASE-FLOW RATIO, CHOICE OF CONTINUOUS PHASE, AND PLATE WETTING CHARACTERISTICS

There is a trend toward increasing H.T.U. values with increasing continuous-to-dispersed-phase flow ratio, as illustrated by Figure 13. Consequently, this trend being attributed to the increase in the interphase contact area as the dispersed-phase relative flow increases, it is usually advantageous from the extraction-effectiveness standpoint to make the phase with the smaller flow continuous and to disperse the phase with the larger flow. This advantage does not appear fully—sometimes does not appear at all—unless the perforated-plate material of construction selected in each case is preferentially wetted by the continuous phase. With plates preferentially wetted by the dispersed, rather than by the continuous, phase, H.T.U. values are generally higher. This effect is confirmed by visual observation of the dispersed phase, which under these conditions travels through the column in relatively large streams, films, and blobs rather than dispersing as small drops of fairly uniform size and relatively much larger interfacial area.

Typical H.T.U. values and capacities indicating the variation with the choice of the continuous phase, (a) with aqueous-phase-wetted, stainless-steel perforated plates and (b) with organic-wetted, fluorothene plastic plates, are compared in Table 4. Higher capacities are generally obtainable with stainless-steel plates than with fluorothene ones for the systems studied.

For process systems in which it is advantageous to disperse the aqueous phase (i.e., when the aqueous-to-organic-phase flow ratio is high), capacities at least as high as those of stainless-steel plates and H.T.U. values as low as

Table 4.—Effects of Choice of Continuous Phase

System	A/O	Perforated-plate cartridge	Approximate highest flooding V: Organic phase continuous	Approximate highest flooding V: Aqueous phase continuous	Approximate optimum H.T.U., ft.: Organic phase continuous	Approximate optimum H.T.U., ft.: Aqueous phase continuous	Phase wetting plates
1	0.5	*E*	>1,200	2,000	1.4	0.6	Aqueous
1	0.5	E_1	1,200	1,000	0.7	0.8	Organic
2	1.75	*E*	>1,500	3,000	1.0	1.0	Aqueous
2	1.75	E_1	1,300	>2,000	0.9	1.8	Organic
2	1.75	E_2	>2,000	>2,000	0.9	1.1	Org. (heavy) phase wetting top face; aqueous lower face

Table 5.—Effects of Plate Hole Size

System	Perforated-plate cartridge	Hole size, in.	Highest flooding V	Optimum H.T.U., ft.: At ⅓ to ½ of flooding V	Optimum H.T.U., ft.: At ⅔ of flooding V
1	*E*	0.125	2,000	0.6	0.7
1	G	0.060	1,000	≤0.7	≤0.7
2	*E*	0.125	3,000	1.0	1.0
2	G	0.060	1,700	0.8	0.8
3	*E*	0.125	1,700	1.5	
3	G	0.060	1,200	≤1.2	
4	*E*	0.125	1,800	2.1	2.5
4	G	0.060	>1,000	≤1.0	≤1.0
18	*B*	0.188	2,000	1.3	1.7
18	*E*	0.125	2,000	1.0	1.5

Table 6.—Effects of Perforated Area

System	Perforated-plate cartridge	% Free area	Highest flooding V	Optimum H.T.U., ft.: At ⅓ to ½ of flooding V	Optimum H.T.U., ft.: At ⅔ of flooding V
17	C	10	2,300	≤1.2	≤1.1
17	*E*	23	3,000	0.9	1.1
17	*F*	40	3,700	1.3	
18	C	10	1,400		≤1.5
18	*E*	23	2,000	1.0	1.5
18	*F*	40	Ca. 2,000	1.2	

Table 7.—Effects of Plate Spacing

System	Perforated-plate cartridge	Plate spacing, in.	Highest flooding V	Optimum H.T.U., ft.: At⅓ to ½ of flooding V	Optimum H.T.U., ft.: At ⅔ of flooding V
2	*E*	2	3,000	1.0	1.0
2	*J*	1.4	2,000	1.1	≤1.7
17	*L*	4	3,800	0.9	1.8
17	*K*	3	3,000(est'd)	1.0	
17	*E*	2	3,000	0.9	1.1
18	*L*	4	2,500	1.3	1.8
18	*K*	3	2,500	1.3	1.9
18	*E*	2	2,000	1.0	1.5

Table 8.—Effect of Plate-to-Wall Clearance on H.T.U.*

System	(H.T.U. with $\Delta D = 0.125$) / (H.T.U. with $\Delta D = 0.015$)
1	1.0
2	1.5
11	1.0
18	1.1

* Cartridge *E*, aqueous phase continuous.

Table 9.—Effect of Concentration on H.T.U.*

a	*af*	H.T.U., ft.: With 0.4 *M* *U* in feed	H.T.U., ft.: With 0.04 *M* *U* in feed‡
0.5	60	1.4	2.5
1.0	70	1.0	2.0
1.0	80	1.2†	1.6

* System 2, cartridge *E*, aqueous phase continuous, V = 1,500.

† A/O = 2.0 (other data obtained at A/O = 1.7).

‡ It is thought that with the dilute feed a higher amplitude-frequency product may have been required to achieve optimum phase dispersion near the feed point, which in turn affected the fineness of the phase dispersion throughout the column. This phenomenon may have magnified the apparent effect of dilution on H.T.U.

those obtained with fluorothene plates may often be attained by the use of "dual" plates, i.e., plates with one plastic (organic-wetted) and one stainless-steel (aqueous-wetted) face (see example in Table 4). The dual plates are oriented with the plastic face toward the organic-phase inlet end of the column (i.e., upward when the organic is the heavy phase, downward when the organic is the light phase).

EFFECTS OF PLATE GEOMETRY

Design of the perforated plates for a given application generally involves a compromise between the desiderata of high capacity and low H.T.U. values. Capacity and H.T.U. both increase with increasing hole size, plate spacing, and percentage of free (perforated) area of the plates. Perforated-plate cartridge *E*, with ⅛-in. holes, 23% free area, and 2-in. plate spacing, often represents a satisfactory compromise between the conflicting functional requirements.

Tables 5, 6, and 7 indicate the effects on column performance of stainless-steel perforated-plate hole size, free area, and plate spacing respectively. The comparison shows up to one-and-a-half- to twofold variations in capacity and H.T.U. as each of these geometry factors is varied three- to fourfold in the neighborhood of the cartridge-*E* geometry.

An increase in the mean diametric clearance between the plates and the wall of a 3-in.-diam. column from 0.015 to ⅛ in. has in most cases been found to exert little or no adverse effect on H.T.U. values. With system 2, however, with a high (close to 0.5) specific-gravity difference between the phases and with the phase densities and uranium concentrations highest at the top of the column, there was enough channeling along the column wall with the wider clearance to cause an approximately 50% increase in H.T.U. (Table 8).

EFFECTS OF DIFFUSING COMPONENT CONCENTRATION

Height-of-transfer-unit values are generally higher at the dilute end of a column than at the concentrated end, as indicated by (*a*) raffinate-phase sam-

Table 10.—Effect of Column Diameter on H.T.U.*

System	H.T.U., ft. 3-in. diam.	8-in. diam.	Remarks
1	0.8	0.8	$V = 1{,}100$, $af = 55$
1	0.9	0.8	$V = 1{,}600$ $af = 55$
2	1.1†	1.5	$V = 1{,}000$, $af = 70$
2	1.0	1.5	$V = 1{,}500$, $af = 70$
17	1.0	1.9†	$V = 1{,}500$, $af = 55$
17	1.1†	1.3	$V = 1{,}500$, $af = 70$
17	1.6	2.0	$V = 2{,}000$, $af = 55$
17	1.1	1.6	$V = 2{,}000$, $af = 70$
18	1.5	1.4	$V = 500$, $af = 45$
18	1.2	1.5	$V = 800$, $af = 45$

* Cartridge *E*, aqueous phase continuous, $a = 0.9$ to 1.0.
† Interpolated.

ples taken at intermediate points, (*b*) visual observation of the uranium-yellow color gradient in a glass column, (*c*) over-all H.T.U. determinations with columns of different plate-section heights, and (*d*) H.T.U. determinations with varying diffusing-component (uranium) concentrations in the feed (Table 9). Aggravation of any channeling tendencies with increasing column height is probably a contributing cause of the higher H.T.U.'s in taller columns.

Application of Results to Columns of Larger Diameter

The limiting superficial volume velocities and limiting pulse amplitudes and frequencies for stable operation are not appreciably affected by scale-up of the column diameter from 3 to 8 in. The greater channeling tendency in the larger column, however, often results in a slight (though sometimes as much as about 50%) increase in H.T.U. values, as indicated in Table 10.

Although transition from stable, emulsion-type to unstable operation occurs at similar conditions in columns of different diameter, a 3-in. column sometimes undergoes complete flooding more readily than a larger column. This is attributed to the fact that in a highly unstable operation a fist-size glob of coalesced dispersed phase, which fills the entire cross section of the 3-in. column, may there obstruct the countercurrent flow of the phases sufficiently to cause a complete flood. In a much larger column a similar glob has ample room to channel past the oppositely flowing continuous phase.

Occurrence and Prevention of Excessive Emulsification

Excessive emulsification, which would result in unstable operation or flooding, may normally be prevented without impairment of H.T.U. values by the proper selection of pulsing conditions and superficial volume velocities for the chemical system and perforated-plate cartridge design involved. However, in some unusual cases special problems have been encountered as a result of (a) surface-active impurities causing excessive emulsification, (b) great differences in the ease of phase dispersion in different portions of the column, and (c) excessive emulsion build-up at the interface.

Pulse Columns vs. Packed Columns

The most important advantage of pulse columns over packed columns is the fact that for the same extraction duty they can be made much shorter. Table 11 shows two- to threefold transfer-unit height reductions on transfer from packed to pulse columns.

Additional advantages of pulse columns are the less pronounced dependence of H.T.U. values on superficial volume velocities and the greater ease of a temporary shutdown and start-up with the property of no flow through the plates in the absence of pulsing.

The need of a pulse generator, with its first cost and maintenance requirements, is a disadvantage.

The study of pulsed perforated-plate columns is continuing. Pulsed columns with stainless-steel or plastic Raschig-ring packing in lieu of perforated plates have been found promising under some conditions and are being investigated further.

Table 11.—Comparison of Pulse and Packed Columns

System	H.T.U., ft. Packed column *	Pulse column †	Flooding *V* Packed column *	Pulse column †
17	2.5-3	1.0	2,000-3,000	3,000
18	2.5-3	1.2	1,000-2,000	2,000

* The higher and lower values are for 1- and ½-in. stainless-steel Raschig rings, respectively.
† Cartridge *E*.

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Notation

- a = pulse amplitude, in. (The term *amplitude* as used here indicates the movement of the column contents between the two extreme positions of the pulse, i.e., twice the movement between one extreme and the mean position.)
- A = aqueous phase.
- A/O = aqueous-to-organic-phase volume flow ratio.
- D = column diameter, in.
- ΔD = diametric clearance between perforated plates and column wall, in.
- f = pulse frequency, cycles/min.
- H.T.U. = height of a transfer unit, over-all raffinate-film basis (i.e., over-all aqueous-film basis for uranium transfer from the aqueous to the organic phase, as in systems 1, 3, 5, 11, and 17) and over-all organic-film basis for transfer from the organic to the aqueous phase, as in systems 2, 4, 6, 12, and 18). Calculated by procedures discussed in Reference (2).
- O = organic phase.
- V = superficial volume velocity, sum of both phases, gal./(hr.)(sq.ft. of column cross section).

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(Presented at A.I.Ch.E. Ann Arbor meeting.)

the "pump-mix" mixer settler
a new liquid-liquid extractor

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The design and operating characteristics of a new type of mixer settler for liquid-liquid countercurrent extraction are described. Interface control is achieved without instrumentation, and the stage arrangement is compact and requires less height than does usual contacting equipment, an advantage for a cascade of contactors operating in series.

Effects of impeller speed and blade arrangement on the mixing intensity, which in turn determines the stage efficiency, are shown. The capacity of the unit was found to be determined by the disengaging time and emulsion-forming characteristics of the system under test rather than by the pumping capacity of the impeller. High stage efficiencies were obtained over the entire flow range of the unit.

With the system methyl isobutyl ketone–water–acetic acid, a run was made extracting acetic acid from water into the ketone in an eight-stage pilot-plant unit. As calculated by the McCabe-Thiele method, the number of theoretical stages corresponded to an average stage efficiency of 95%.

For mathematical data, order document 4336 from A.D.I. Auxiliary Publications Photoduplication Service, Library of Congress, Washington 25, D. C., remitting $1.25 for microfilm or $1.25 for photoprints.

In a continuous liquid-liquid extraction process the function of the contactor is to provide a large interfacial area for mass transfer between the two liquid phases. The method for dispersing one phase within the other to create this area varies with the type of contactor. In packed or sieve-plate columns, which may be considered nonpowered contactors, the dispersion depends upon the degree of mixing created as the phases flow countercurrently by density difference, with the packing or plates serving to create turbulence and phase surface area. This type of contactor has the disadvantage that the degree of dispersion is not an independent variable but depends, in addition to the contactor design, upon the mass flow rates and physical properties of the phases. To overcome this disadvantage, various types of powered contactors, such as mixer settlers, pulse columns, and centrifugal extractors, have been designed in which the degree of dispersion is controlled. Usually in a mechanically powered contactor the maximum mixing intensity is limited by the necessity for subsequent separation of the phases. Too violent dispersion may result in emulsification and poor settling, which limit the capacity and efficiency of a multistage contactor.

The ideal contactor requires a minimum investment for both associated equipment and building, maintains high efficiency over a wide range of operating conditions, has high capacity with low holdup, is reliable in operation with

simple controls and minimum maintenance requirements, and is flexible for process variations.

This paper describes a new type of mechanically powered contactor, the pump-mix mixer settler, which satisfies these requirements to a high degree. No attempt is made to describe the development program leading to the present design. This article is primarily a description of the mechanical details of the unit. Extensive performance data are planned for future papers; however, some data from the development studies are included to illustrate effects of impeller speed, blades, and baffle design upon stage efficiency.

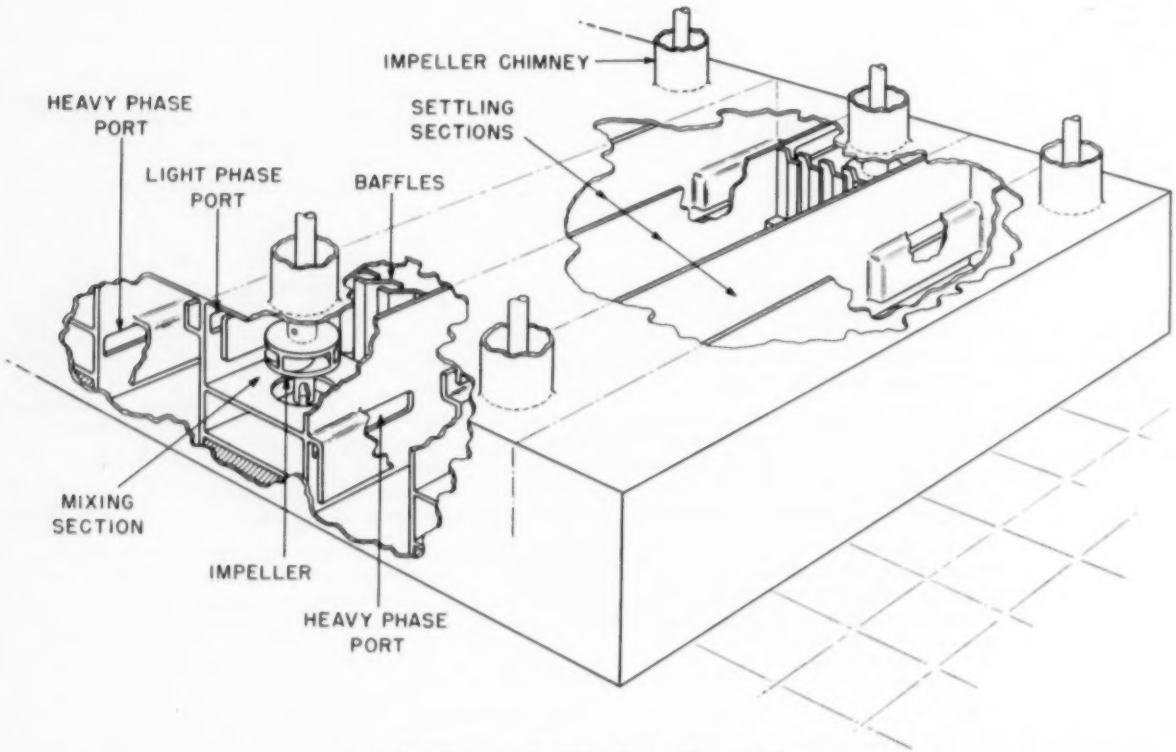

Fig. 1. Pump-mix mixer settler showing adjacent stages.

Mixer-settler-type liquid-liquid extractors have been in use since about 1904 (1). The earliest continuous counter-current mixer settler appears to be that of Barstow (1), in which the flow pattern of the two phases is cocurrent through each mixing and settling stage but countercurrent over-all. The devices of Van Dijck (2) and Cornish (3), which have many agitators on a common shaft with settling zones between agitators, may be regarded as tilted columns because the flow is countercurrent through each mixing and settling stage as well as over-all.

The Holley extractor (4) is similar to the Barstow device with the addition of a valve-controlled line that permits recirculation of the heavy phase from the settling section to the mixer. A modification of the Barstow device developed about 1949 included a separate antechamber for light and heavy inlets which, together with antiswirl baffles in the mixing region, minimized the transmission of turbulence and back mixing to the settling sections. The foregoing device, like the Barstow and Holley extractors, depends on gravity flow of both the light and heavy phases. As the number of stages is increased, the total change in liquid-liquid interface level from one end of the unit to the other becomes quite large and requires that the individual stages be made sufficiently deep [for example, 42 in. for eight stages in one instance (1)] or else that provision be made for tilting the entire array. Deep stages are sometimes undesirable because of the greater ratio of holdup to throughput. Tilting is mechanically inconvenient and may require continuous adjustment as density gradients vary.

The Edleanu extractor (5) consists of a cascade of mixing and settling vessels with valve-controlled gravity flow of the heavy phase and interstage pumps for the transfer of the light phase.

The extractor of Gordon and Zeigler (6) uses a shrouded impeller which produces a pumping action. Adjustable valves are used to control the height of the interface in each stage. The extractor of Mensing (7) is similar in that the inlet light- and heavy-phase streams are fed to the intake of an impeller (a screw propeller in the case of the Mensing device) which produces a net pumping action. The level of the interface in the Mensing device is controlled by an adjustable weir on the heavy-phase outlet from each stage, a device that also provides some recirculation of mixed phases to the mixer. The Gordon-Zeigler and Mensing extractors do not require tilting but require interface controllers for systems with large density changes from stage to stage due to transfer of solute.

The Pump-Mix Mixer Settler

The pump-mix mixer settler is a horizontal contactor in which the mixing intensity, automatic liquid-liquid interface control, and hydraulic head for heavy-phase flow are provided by the impeller. The need for individual stage-interface sensing and control devices or for a tilted unit to provide hydraulic head is eliminated. A contactor consists of a number of stages, each stage containing a mixing section and a settling section. Over-all flow through the unit is countercurrent, but through each stage it is cocurrent. Figures 1 and 2 illustrate the design and flow pattern.

Every mixing section has an impeller driven by a shaft that enters the mixing section through the top of the stage. Figure 3 shows how the impeller acts as a centrifugal pump providing the head for flow of the heavy phase. When the shaft rotates, liquid is drawn up through the hollow tube and discharged through the holes in the impeller. For a particular impeller, the capacity of the pump is a function of the impeller speed. The impeller is designed so that over a wide range of speeds its capacity is greater than the heavy-phase flow rate. As the capacity of the pump is greater than the heavy-phase flow, the interface will fall below the impeller tip, thereby causing the impeller to draw the mixed phases from the upper portion of the mixing section down through the hole in the horizontal plate (*c* in Figure 3) and this material is recycled until the interface again builds up to the impeller tip. The net result is a "make-and-break" effect between the impeller tip and the heavy-phase–mixed-phase interface. The level of the impeller tip (which is the same in all stages) controls the position of the interface in the preceding stage. The only level device required is a weir to drain the heavy-phase stream from the last stage.

The horizontal plate below the impeller confines the mixing to a relatively small volume. A decrease in the size of the hole in the horizontal plate affects the pressure drop between the two compartments of the mixing section and thus decreases the volume of recycled phase.

The heavy-phase inlet section is similar to the inlet of a centrifugal pump. If the hole in the recirculation plate is small, a suction head is created which draws heavy phase from the preceding settling section and lowers the interface level. Normal design requires that minimum hole size be such that with normal operating levels, if the inlet streams to the unit are stopped and the impellers are kept rotating, the settling-section interface is not brought down to less than ½ in. above the inlet to the heavy-phase port. If the hole size is larger than the minimum necessary to permit this "free wheeling," the unit is still completely operable but the mixing intensity may be decreased slightly. The diameter of the hole is therefore not a critical dimension over a wide range.

The function of the baffles between mixing and settling sections is to separate the turbulent mixing zone from the settling zone to permit disengaging of the phases. The *L*-shaped and vertical baffles on the light-phase inlet to the mixing section (*b* in Figure 3) prevent mixed phases from being thrown into the previous settling section and causing a loss in efficiency by back mixing. The inverted *L*-shaped baffle on the heavy-phase inlet (*a* in Figure 3), usually called the chimney, serves a different function. It is desirable to draw off the heavy-phase effluent of any stage from the bottom to avoid stagnant layers. A port at the bottom of the stage between the settling section of one stage and the heavy-phase inlet section of the next would accomplish this most simply; however in some extraction systems, owing to mass transfer of the solute there is a considerable change in the density of one or both phases. Figure 3 shows that two adjacent stages can be considered as two legs of a manometer; if the port were at the bottom, it can be seen that when the densities of the heavy phase in the two stages differ markedly, the location of the interface may be affected. This difference is eliminated by the chimney baffle, which in effect makes the mixing-section heavy-phase leg of the same density as that of the settling-section heavy-phase leg. The effect of the density difference between mixed phases and light phase as well as pressure drops across the ports and baffles is compensated for by the equilibrium position of the interface in the settling section. A mathematical treatment of this effect is presented in the Appendix.*

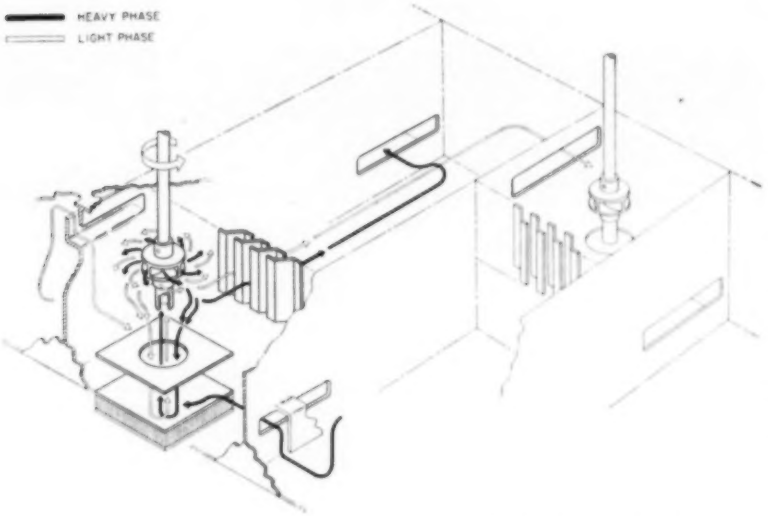

Fig. 2. Schematic drawing of pump-mix mixer settler showing direction of flow.

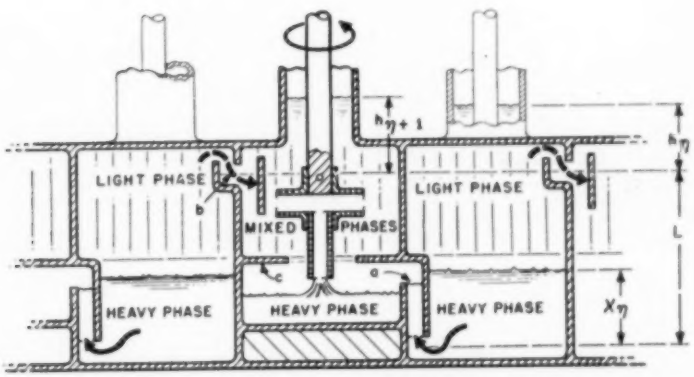

Fig. 3. Pump-mix mixer settler; elevation showing three adjacent stages.

Design Details

Figure 4 shows the pump-mix impeller. In effect, it is a low-head, high-capacity, closed centrifugal pump impeller of four vanes connected to a hollow dip leg. When mixing blades are used, they are preferably fastened on the top disk and extend radially inward from the outer rim.

The square or rectangular mixing cross section, used to facilitate construction, also elimi-

* See footnote on page 403.

nates the need for vertical antiswirl baffles on the walls of the mixing section. However, blades on the impeller create additional turbulence and are generally used on systems which can withstand vigorous mixing without excessive emulsification and resultant difficult separation. In addition, it was found advisable to insert a T-shaped vertical baffle in front of the light-phase inlet port so that the incoming stream is circulated around at least 270° of the impeller before being discharged into the settling section. This baffle also prevents mixed phases from back mixing through the light-phase port into the previous settling section. The direction of rotation of the impeller in relation to the angle of the baffle between mixing and settling sections is important. To confine the turbulence to the mixing section, the direction of rotation should be such that liquid leaving the impeller impinges on the closed end of the baffle.

Figure 5 shows the evolution of the correct relationship of blades and baffles. The following list gives the trend in the average stage efficiency obtained in runs on the same system at the same flow rates and impeller speed for (a) impeller with no blades and no light-phase inlet baffle—77% efficiency; (b) impeller with blades but no light-phase inlet baffle—83% efficiency; (c) impeller with blades and light-phase inlet baffle—99% efficiency.

In all the cases the direction of the impeller in relation to the angle of the baffles in the opening to the settling section is correct. A reversal of impeller direction in case (c) caused discharge of some of the light phase before it had circulated in the mixing section, and the average stage efficiency dropped to 88%.

The box-type construction used for multistage units is compact and simple to fabricate. Figure 6 shows a typical sixteen-stage pilot plant unit. The individual stage dimensions are width, 3 in.; height, 5 in.; and length, 11 in. The mixing section is 3 by 3 by 2½ in. high with a recirculation hole 1⅞ in. in diam. The impeller diameter is 1⅞ in. with dip leg 7/16 in. I.D. and 2 in. long. Four blades ¼ in. long and 3/16 in. high are fastened to the top disk.

The range of capacity of this unit for a variety of organic-aqueous systems was found to be 0.2 to 0.5 gal./min. total flow of both phases.

The shafts can be driven by individual electric motors or by a chain, belt, or gear system. All impellers in a unit rotate at the same speed, which however it should be possible to vary. For the unit shown in Figure 6, a range of 300 to 600 rev./min. is adequate.

Efficiency and Operating Range

The pump-mix mixer-settler design confines the mixing in each stage to a relatively small volume of the entire stage, and the mixing intensity can be varied over an extremely wide range by varying both the impeller-blade area and its speed. Thus a high mixing efficiency can be maintained over the entire hydraulic capacity of the contactor and also over a wide ratio of phase flows. Runs at high efficiency have been conducted at a light-phase-to-heavy-phase flow ratio of 10 to 1 and at 1 to 10 in the same unit. Figure 7 shows stage efficiency as a function of stirrer revolutions a minute. These data were obtained with a bladed rotor 1 in. in diam. in a single-stage unit and illustrate the typical curve obtained for a pump-mix impeller. It is apparent that for the particular system 800 rev./min. is optimum. Increasing the speed not only does not increase the efficiency but does increase the dispersion so that settling is more difficult and capacity decreased.

Capacity and Holdup

In general the capacity of the mixer settler is determined by the size of the settling section. Pumping capacity is readily increased by increasing the impeller speed. The length of time required for the separation of the mixed phases determines the size of the settling section and for a unit of definite size determines the total liquid-volume capacity. The settling time, which varies widely for different systems, is determined reliably only by actual operation on the system intended to be used.

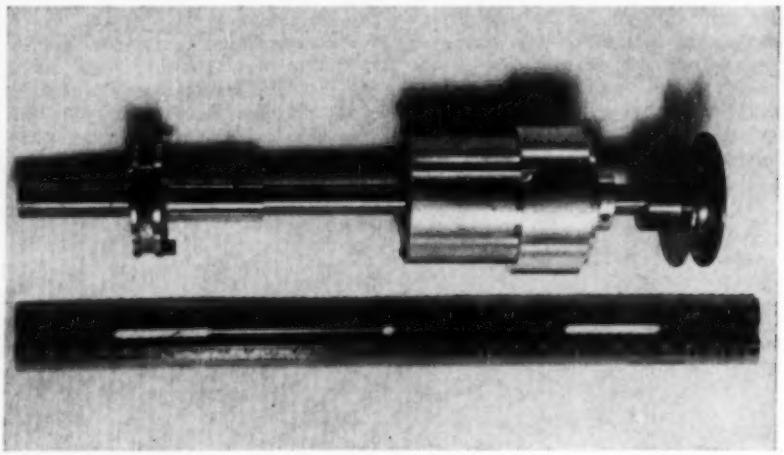

Fig. 4. Pump-mix impeller.

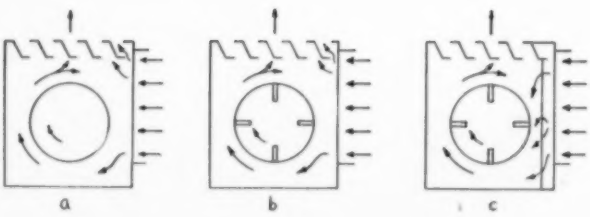

Fig. 5. Evolution of blade and baffle design.

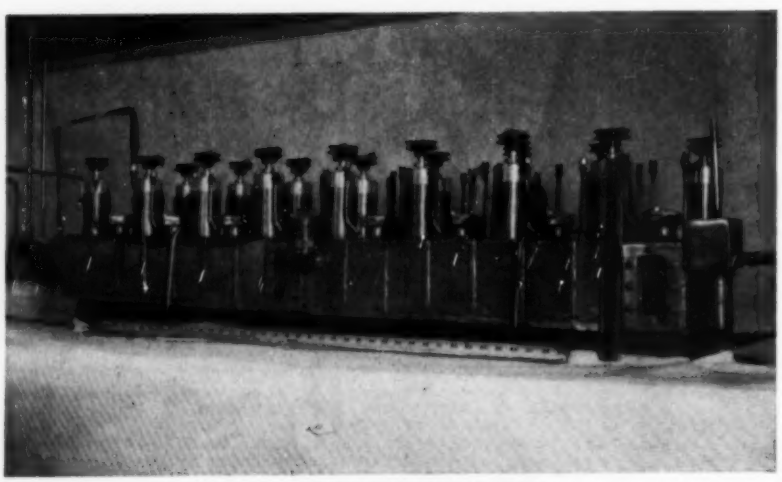

Fig. 6. A 16-stage pump-mix mixer settler.

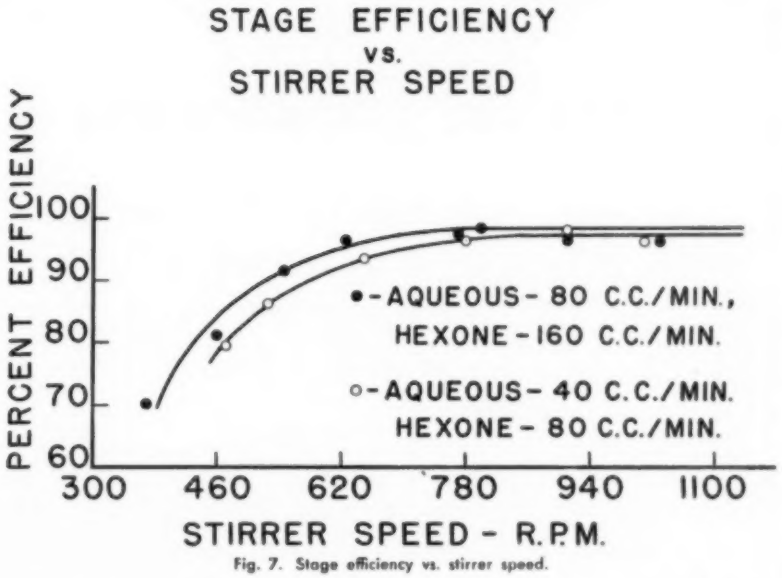

Fig. 7. Stage efficiency vs. stirrer speed.

The size-capacity characteristic is one of the bases for comparison of the relative effectiveness of different types of extraction equipment. The volume occupied by the apparatus is important, as space requirements and extractor cost, including packing if any, would be approximately in proportion to the volume; if volume is considered the important size variable, a quantitative measure of the effectiveness of the equipment would be

$$E_f = K\frac{NF}{V} = K\frac{1}{t} = K\left(\frac{1}{t_m + t_s}\right) \qquad (1)$$

where

E_f = contactor effectiveness
N = number of theoretical stages
F = total flow rate, cu.ft./hr.
V = total contactor volume, cu.ft.
t = holdup time/theoretical contacting, hr.
t_m = holdup time in the mixing section, hr.
t_s = holdup time in the settling section, hr.

K is a dimensional constant depending upon the solvent-extraction flowsheet.

In terms of the variables usually considered in packed-tower design, Equation (1) becomes

$$E_f = K\frac{NF}{(Ah + V_{in} + V_{out})}$$

$$= K\frac{G}{\rho_{avg}\left(HETS + \frac{V_{in}}{NA} + \frac{V_{out}}{NA}\right)}$$

where

G = mass flow rate/unit area, lb./(hr.)(sq.ft.)
ρ_{avg} = average density, lb./cu.ft.
$H.E.T.S.$ = height equivalent to a theoretical stage, ft.
V_{in} = volume of the inlet section, cu.ft.
V_{out} = volume of disengaging section, cu.ft.
A = total cross-sectional area of the column, sq.ft.
h = height of packed section, ft.

A limited amount of data on similar systems for comparison of the pump-mix mixer settler with packed columns indicates that the contactor effectiveness E_f is approximately the same for both types.

Reliability

The only moving part in the operation of a pump-mix mixer settler is the impeller, which is integral with the drive shaft; no seals or bearings other than those in the motor or pulley are required. The shutting off of a single impeller ordinarily does not stop the operation of the contactor. Two or three adjacent impellers must fail before a unit floods. The impeller assemblies can be replaced without affecting the remainder of the unit. Control of the interface in the aqueous outlet stage by a mechanical weir or nitrogen pressure-controlled jack leg has proved to be simple and trouble free.

Hydraulic Head

In a pump-mix mixer settler the impeller in any stage controls the level of the heavier phase in the preceding stage. Therefore no pressure head outside the unit is required to produce flow of the heavy phase. The light phase does flow through the unit by gravity but owing to the pumping action of the impeller and proper port design a drop of less than ½ in. a stage occurs. This results in small differential heights of the light-phase surface in the standpipes for a cascade of units.

Process Flexibility

The mixing intensity of a pump-mix mixer settler is varied by changing the stirrer speed or blade area, and thus flexibility is provided in processing various solvent systems. Although the capacity may be affected by a change in system, the operability and efficiency are not.

The particular advantages of this unit over column contactors for research and development are

1. Stage samples are simply obtained, providing in a single run a complete profile of all components in the liquid-liquid extraction process.
2. The unit may be shut down and started up without upsetting equilibrium conditions or draining the unit. It is possible to run for 8 hr., shut down for 16 hr., and start up again, collecting equilibrium product immediately. If the feeds and stirrers are shut off simultaneously, the levels remain stationary and the equilibrium conditions are not upset.
3. Runs can be made with predictable efficiency, providing a maximum of design data on theoretical stage requirements with a minimum of runs.

Experimental Extraction Data

A solvent-extraction run with a simple three-component, two-phase system was made to provide an example of the application of the pump-mix mixer settler. The stage-by-stage data obtained are typical of other systems which have been tested. They are included in this paper to illustrate the efficiency of the pump-mix stages and the type of data which can be obtained for flowsheet evaluation.

The system used was acetic acid–hexone–water. In the run to be discussed, the system was further simplified by preequilibration of the feed streams. The hexone was equilibrated with water and the aqueous feed with fresh hexone. The transfer of the two solvent components is minimized in this way, and the system can be treated as two immiscible solvents and the solute, acetic acid. In the range of acetic acid concentrations used (below 1 M/L in each phase) the mutual solubility of the water and hexone is nearly constant (see Table 1) and the assumption is therefore valid.

In a run made with the conditions summarized in Table 2, the flow rates were chosen so that a concentration change in the aqueous stream of approximately a factor of five would be obtained with eight theoretical stages. This was done so that a simple titration method would be sufficiently accurate for analysis of all samples. The

aqueous feed entered the bank at stage 1 and left at stage 8. The extractant (hexone) entered at stage 8, flowed countercurrent to the aqueous stream, and left the bank at stage 1.

Samples of both phases in all eight settling sections were withdrawn at the end of the run, after approximately four times the holdup volume was fed to the bank. Each sample was divided into two parts; one portion was analyzed for acetic acid, the other was "equilibrated" with a portion of other phase sample withdrawn from the same stage, and both phases were analyzed. The samples were titrated with 0.1 M sodium hydroxide to a phenolphthalein end point, the maximum error being estimated at ±5%.

The stage data are given in Table 2 and are shown plotted in a conventional McCabe-Thiele diagram in Figure 8. The equilibrated-stage sample analyses were also plotted. Comparison of the equilibrium line slope with measurements of the distribution coefficient for the same system is shown in Table 3. The agreement is within 6%.

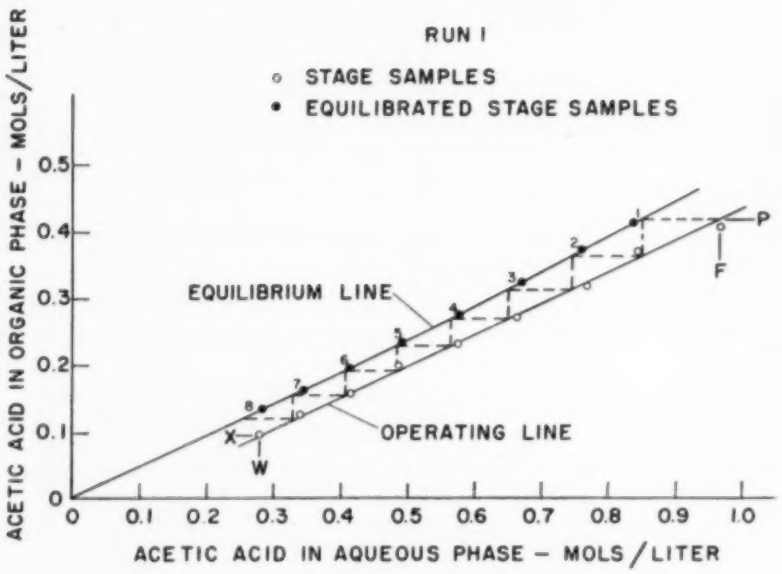

Fig. 8.

Table 1.—Mutual Solubilities of Aqueous and Organic Phases (8)

System: Acetic Acid–Hexone–Water, 20° C.

Aqueous phase		Organic phase	
Acetic acid, moles/liter	Hexone, wt. %	Acetic acid, moles/liter	Water wt. %
0.0	1.5	0.0	2.5
0.8	1.5	0.7	3.5
1.6	2.0	1.4	6.0

Table 2.—Extraction of Acetic Acid from Water with Hexone

	Run 1
Acetic acid in aqueous stream, M/L	0.965
Acetic acid in hexone stream, M/L	0.095
Aqueous feed rate, cc./min.	263
Hexone feed rate, cc./min.	526
Stirrer, rev./min.	500
Number of stages	8

Stage Data

Acetic Acid Concentration, moles/liter

	Unequilibrated		Equilibrated	
Stage	Aqueous	Organic	Aqueous	Organic
1	0.840	0.402	0.835	0.410
2	.765	.364	.755	.369
3	.660	.313	.665	.320
4	.573	.269	.575	.273
5	.483	.229	.487	.232
6	.411	.194	.412	.193
7	.337	.155	.340	.159
8	.276	.124	.279	.132
Composite end stream	0.269	0.41		

Table 3.—Comparison of Acetic Acid Distribution Data

System: Acetic Acid–Hexone–Water, 20° C.

Acetic Acid Concentration Range: 0.1–1.0 M

	Distribution coefficient, M', organic/M', aqueous
Run 1	0.47 (0.1–0.5 M in aqueous)
	0.48 (0.5–0.9 M in aqueous)
Farmer (9)	0.50

The over-all stage efficiency was computed from the ratio of the number of theoretical stages required for the observed acid loss as determined from the McCabe-Thiele diagram to the number of actual stages used in the run (eight stages). The number of theoretical stages required is 7.6 within the accuracy of the plotting method, which is estimated to be ±5%. The over-all stage efficiency is therefore 95 ±5%.

Acknowledgment

The authors wish to express their appreciation of the assistance of their fellow workers at the Knolls Atomic Power Laboratory, particularly J. H. Holmes and A. C. Schafer, Jr., for assistance in the design and operation of the equipment and of Dr. B. F. Rider for analytical determinations.

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Presented at A.I.Ch.E. San Francisco meeting.

a self-cleaning air filter

details of the Hersey reverse-jet filter

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To the chemical engineer the Hersey reverse-jet filter may at first seem merely a new method of accomplishing the back-washing of an air filter, but this is a misleading oversimplification. The Hersey method might better be expressed as an objective—to use a thick, dense filter medium of fine fibers so that high filtering efficiency will not depend primarily on the formation of a filter cake and to keep the filter medium and its dust deposit porous enough to permit high filtration velocities and yet maintain high efficiency. This objective has been at least partially accomplished, in that a dynamic steady-state condition of dust in and on the filter medium is maintained, the condition being controlled by the pressure drop across the filter.

The most widely developed type of Hersey filter consists of a cylindrical tube, or bag, of filter material such as dense wool felt, which is slowly traversed by a slotted tube that contacts and indents the filter medium and blows a high-velocity jet of gas through the medium in the direction reverse to that of the normal gas flow. The contact and indentation of the filter medium is essential, as shown in Figure 1, not only to provide a seal to force the reverse jet through the filter medium, but also to provide flexing action to allow the entrapped dust particles to be blown free by the jet. The general arrangement of the filter- and blow-tube mechanism is shown in Figure 2, which illustrates an early test and demonstration model.

Range of Application

The Hersey filter usually provides 99.9% or better collection efficiency on a weight basis, with some few exceptions to be discussed later. Thus it is adequate from the efficiency standpoint for almost any industrial or commercial task where high efficiency is indicated, and has proved suitable for collection of some types of radioactive dust. It has proved of high efficiency for vaporized silica of 0.6μ mass median size, and since half of this dust on a weight basis is smaller than 0.6μ, presumably the filter is efficient in the submicron range.

Dust loadings on filters in service range from atmospheric air or less up to several hundred grains per cubic foot, as in pneumatic conveying or hammer-mill discharge service. The filtering ratio and pressure drop depend of course on the characteristics of the dust and other factors. When moist gases are filtered, the gas must be kept above the dew point, although infrequent wetting of the filter medium (as from condensa-

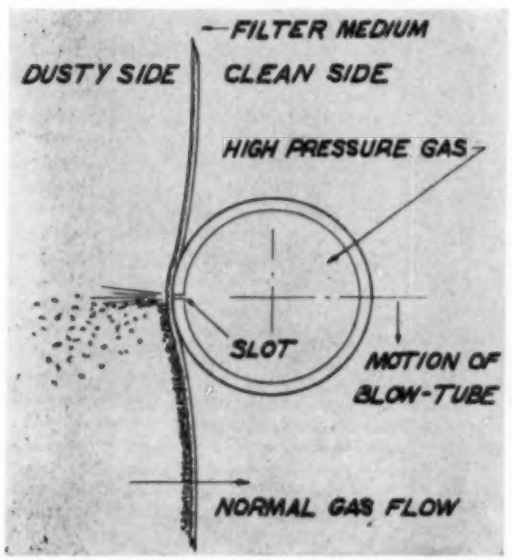


Fig. 1. Contact of blow ring with filter tube.

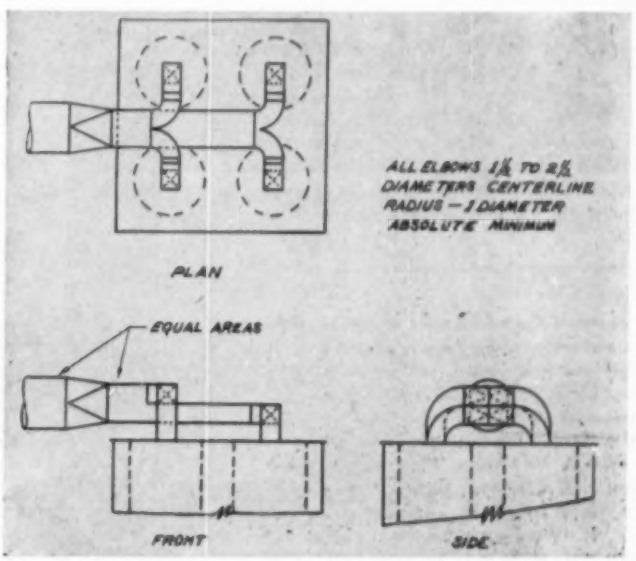
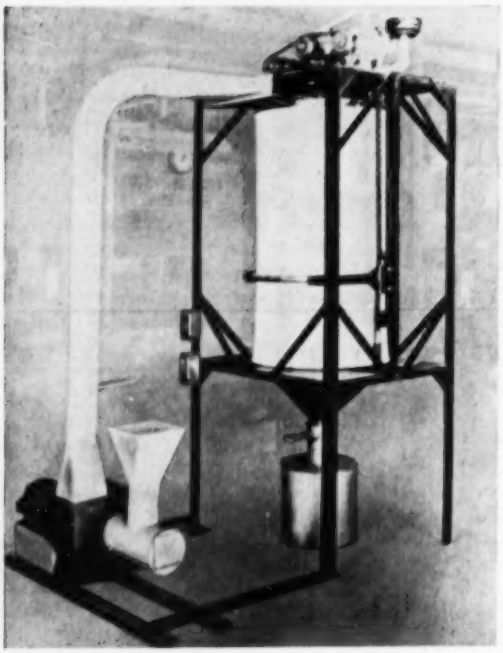
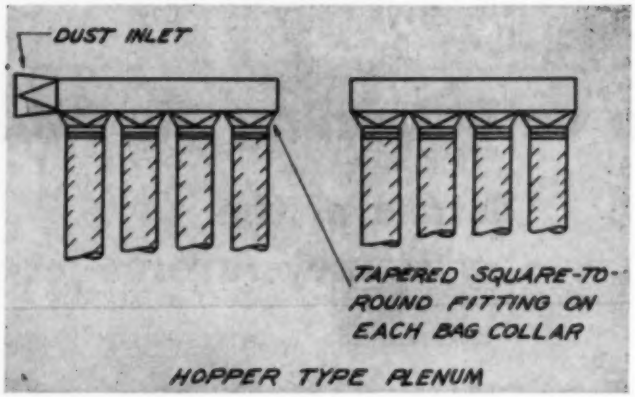


Fig. 3. Inlet manifold sanitary design showing separate ducts to each filter tube.





▲ Fig. 4. Hopper-bottom plenum sanitary design eliminating ledges in plenum.

◀ Fig. 2. Early model of Hersey reverse-jet filter.

tion on a cold start-up) does not appear harmful unless the collected dust is soluble or tends to form a sticky or cement-like mass. Sometimes it is advantageous to warm the reverse-jet air to avoid local condensation.

Most of the limitations of reverse-jet-filter application at present are really limitations of the usable filter media rather than limitations of the basic method. Wool felt, which is generally chosen as the filter medium, is suitable only for temperatures of 190° to 200° F., and mild acid or alkaline conditions. Special treatments of wool felt suit it to certain conditions. Woven fabrics are usually unsuitable because they depend for efficiency upon the formation of a filter cake, and the reverse jet destroys the cake and opens the holes in the weave. Surmounting these limitations depends upon the development of synthetic or inorganic fibers into a truly feltlike material or the development of mechanisms for keeping such fibers in their present form porous. Experimental work with both objectives is being conducted.

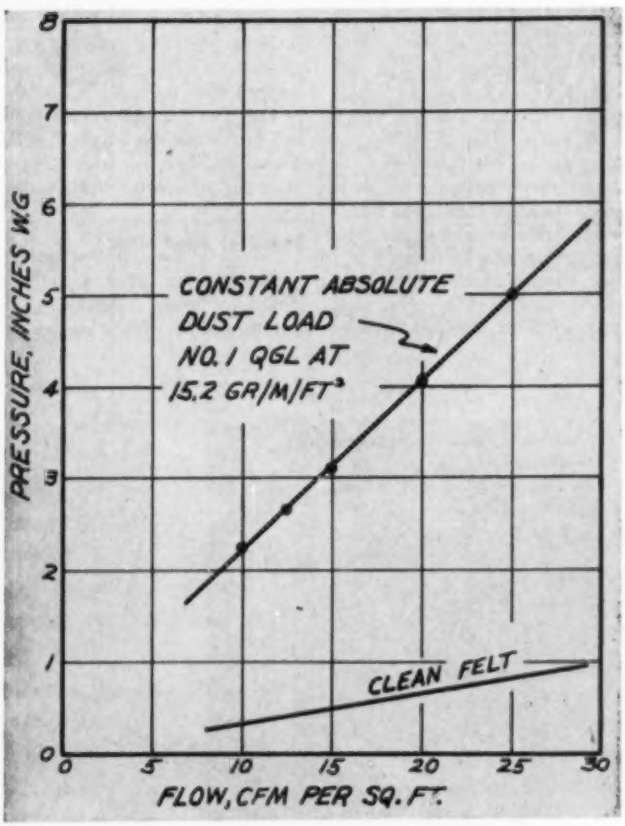


Fig. 5. Pressure-volume relation of air flow through felt with constant dust deposit.

The relatively small number of tubes or bags in a Hersey filter makes possible a sanitary design providing minimum material hold-up and easy cleaning, which are important to the food, color,

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drug, and other industries. Sanitary designs of the inlet manifold type and the hopper-bottom plenum type are shown in Figures 3 and 4.

Operating Characteristics

The variation of filter resistance with gas flow at constant absolute dust load is linear, as shown in Figure 5. The slope of the line depends on the amount and physical characteristics of the equilibrium dust deposit; these particular data were obtained with Quincy No. 1 ground limestone (mass median diam. 9.4μ, standard geometric deviation 2.98) fed at a rate of 15.2 grains/(min.)(sq.ft.) filter area. This linear *P-V* relationship will hold for any given operating unit only if the absolute amount of dust entering the filter is constant. If the total amount (not the concentration) of dust varies with the gas volume, the *P-V* relation will not be linear.

A frequent source of confusion in discussing dust loadings is the long-established habit of engineers of thinking in terms of grains (avoirdupois) of dust per cubic foot of gas. These units actually represent the concentration of dust in the gas, and if the gas volume flowing through the filter is varied, the amount of dust actually handled by the filter varies, even though the concentration may be constant. The operating characteristics of the filter, however, depend more directly on the nature and absolute amount of dust handled. In this discussion, then, absolute dust load will be used, and a suggested unit is grains avoirdupois per minute per square foot active filter area.

Since the *P-V* relation determined in Figure 5 agrees with the theoretical analysis of streamline flow, it is assumed that resistance of the filter will vary with the viscosity and density of the gas in the usual manner, as discussed by Perry (1) and others. Most of the experimental work and field studies on Hersey filters have been made on air as the gas, at or close to the conditions defined by the American Society of Heating and Ventilating Engineers as standard (air at 0.075 lb./cu.ft., 70° F., 29.92 in. Hg abs.).

The variation of filter resistance with dust load at constant gas volume is not linear but exhibits a sharp rise from zero loading and becomes asymptotic at higher loadings, as shown in Figure 6. The quantitative values vary with the physical characteristics of the dust and with variables of the filter such as reverse-jet volume and velocity and blow-ring speed. Apparently, however, all such dusts exhibit a loading-resistance curve of a similar shape. The data shown in Figure 6 were obtained by using electrically fused dolomite (mass median 26μ, standard geometric deviation 5.3) at various concentrations while the air volume was constant.

Considerable time is required to establish an equilibrium condition in the filter medium. A typical resistance-time log is shown in Figure 7, depicting the start-up of a new filter. In view of the long equilibration time frequently experienced, it might be deduced that filtration efficiency might also require a long time to reach the high values noted in Table 1. Unfor-

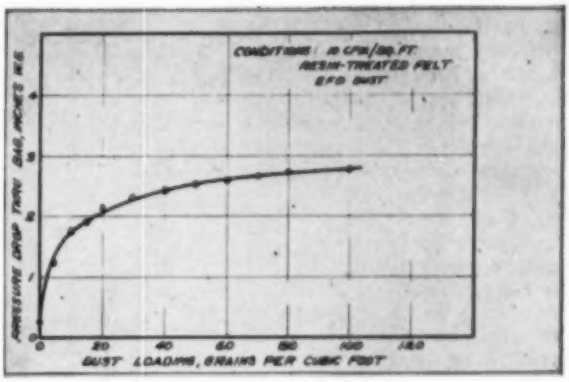

Fig. 6. Resistance dust-loading characteristic at constant gas volume.

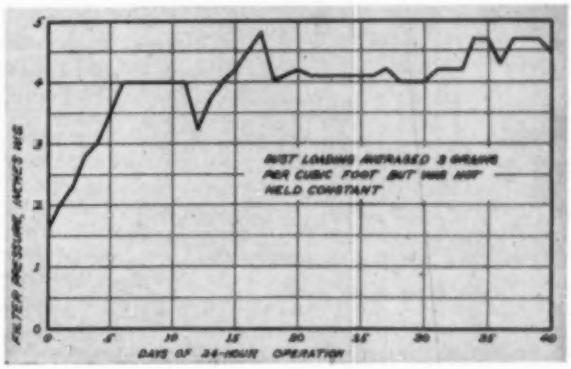
DUST LOADING INCREASED 3 GRAINS PER CUBIC FOOT BUT WAS NOT HELD CONSTANT
FILTER PRESSURE, INCHES W.G.
DAYS OF 24-HOUR OPERATION

Fig. 7. Filter resistance-time log on start-up of a commercial installation showing long equilibration time.

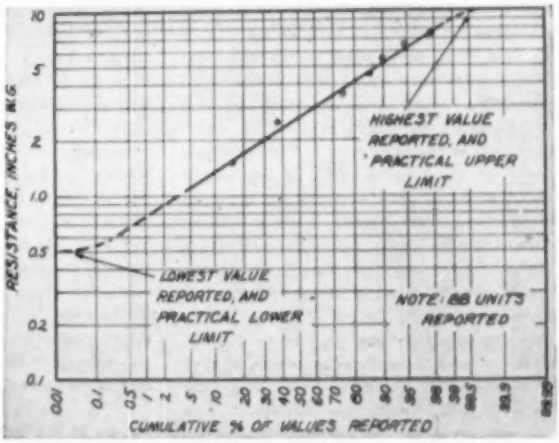
HIGHEST VALUE REPORTED, AND PRACTICAL UPPER LIMIT
LOWEST VALUE REPORTED, AND PRACTICAL LOWER LIMIT
NOTE: 88 UNITS REPORTED
RESISTANCE, INCHES W.G.
CUMULATIVE % OF VALUES REPORTED

Fig. 8. Range of filter resistance.

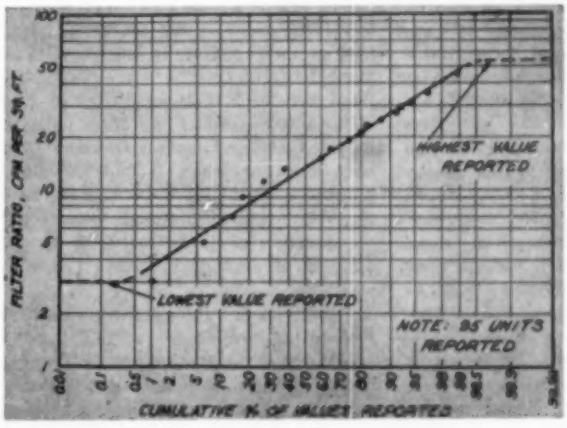
HIGHEST VALUE REPORTED
LOWEST VALUE REPORTED
NOTE: 95 UNITS REPORTED
FILTER RATIO, CFM PER SQ. FT.
CUMULATIVE % OF VALUES REPORTED

Fig. 9. Range of filter ratios.

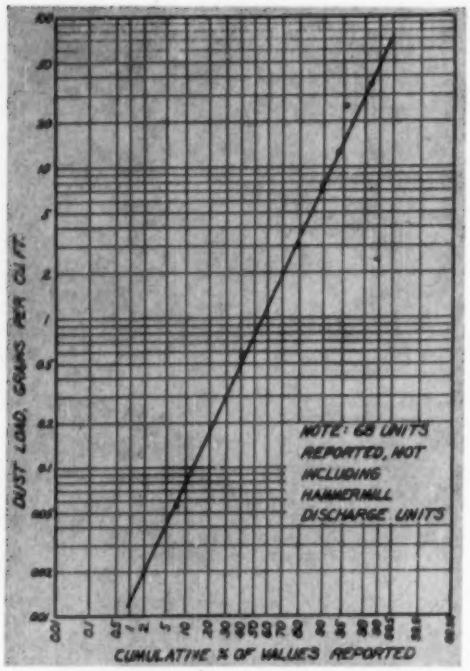
DUST LOAD, GRAINS PER CU.FT.
NOTE: 68 UNITS REPORTED, NOT INCLUDING HAMMERMILL DISCHARGE UNITS
CUMULATIVE % OF VALUES REPORTED

Fig. 10. Range of dust loadings.

straight line on log-probability scales. Such plots mean that the samples follow a skewed Poisson distribution, but no significance is attached to this fact except possibly as an indication that a good statistical sampling has been obtained.

The range of filter resistances encountered is indicated in the logarithmic plot of Figure 8, showing 90% of the values between 1.1 and 6.3 in. water gauge. A lower limit is imposed by the fact that the felt generally used as a filter medium has a resistance of 0.5 in. w.g. at 17 cu.ft./(min.)(sq.ft.) filter ratio when clean. An upper limit is imposed at about 8 or 10 in. w.g. depending on filter-tube diameter since filter resistance in the tubular type must not exceed the mechanical strength of the felt. A low filter resistance is desirable in many applications where the gas moving equipment is a centrifugal fan of the industrial exhauster type, limited to about 15 or 16 in. w.g. static pressure. Another form of filter with a much higher upper limit of resistance will be discussed later.

Filter ratio in dust collecting work is defined as cubic feet per minute of gas per square foot of actual filter area and is equal to the apparent or superficial gas velocity through the filter medium. The range of filter ratios encountered is shown in the plot of Figure 9, showing 90% of the values between 5.3 and 32.5 cu.ft./(min.)(sq.ft.), and 50% above 13 cu.ft./(min.)(sq.ft.). Attainment of such high filter ratios usually means a more compact filter unit with smaller consumption of floor space and less capital investment in the nonfunctional portion of the dust filter, such as housing and support legs.

The range of dust loadings encountered is shown in Figure 10. Dust loadings are usually expressed in grains avoirdupois per cubic foot of gas. Many Hersey filters are used to collect the entire product from swing hammer mills and similar equipment, and although the dust loadings from these machines are in the ranges of several hundred grains per cubic foot of gas, the gas volumes are usually not known with any degree of certainty, and hence these values cannot be reported.

The range of collection efficiencies determined, and the source of the data are shown in Table 1. Most of the results, particularly on the radioactive dust, are based on from five to sixty samples, and the entries are arranged in order of decreasing efficiency. The last eight entries show considerably lower efficiencies than would be expected and are all from a single source. Although these particular units were not observed by the author, it is postulated that gross leakage, as from loose bag collars or holes in the filter, must have been present although possibly not detectable

tunately very few data are available on this point.

A scattering of data indicates that initial efficiencies are reasonably high for the reverse-jet filter when dense wool felt or equivalent filter mediums are used. A test at Harvard (3) presumably (though not so stated) on new wool felt, shows 85.4% weight efficiency on atmospheric air, as compared with 35.5% weight efficiency for woven cotton cloth. An unpublished report of A. D. Little Company (8) shows an initial efficiency on atmospheric air of 70% by dirt-discoloration test. Presumably efficiencies would be much higher on a weight basis. Assuming that this test operated 24 hr./day, approximately 1,000 hr. of operation without blow-ring operation were required for the efficiency to reach the reported maximum of 97% by dirt-discoloration test. Later the blow rings were run both in continuous operation and on pressure control, and the filtration efficiency was determined on a particle count basis while atmospheric air was filtered. Again weight efficiency would presumably be higher than particle count efficiency. Seven efficiency determinations on this basis ranged between 96 and 98%, and one value was 93.6%.

If it is assumed that the atmospheric air used by A. D. Little for 1,000 hr. had an average dust content for such air of 10^{-5} grains/cu.ft., this concentration would be 10^{-5} times lower than an ordinary industrial dust load of 1 grain/cu.ft. If it is further assumed that the initial time-efficiency characteristic depends primarily on the amount of dust which has entered the filter, the filter might be expected to reach normal efficiency in $1{,}000 \times 10^{-5}$ hr. if it were on a 1-grain dust load, or in 0.1 hr. This deduction based on the A. D. Little work does not agree with the observed experience of several hundred hours required to reach equilibrium in terms of filtering ratio and resistance; therefore there is apparently little if any relation between equilibrium in terms of performance and equilibrium in terms of efficiency. In most applications, since the initial period of less than 99.9% efficiency is very short, the question has only academic significance. The only other test concerning the relation of time and efficiency was that of Caplan and Mason (6), which was obtained on a dust exhibiting bad seeping qualities and which therefore may not be typical. In that instance the percentage passing the filter (on the order of 0.1%) increased beginning with the first day of use for plain wool felt; for H.C.E. treated felt, the percentage passing (on the order of 0.02%) first decreased from the fifth to the tenth day, and then increased.

Range of Performance and Efficiency

The filtering ratio (cu.ft./(min.)(sq. ft.) filter area), filter resistance, dust loading, and collection efficiency of a number of Hersey filters in actual operation have been compiled (Figures 8 to 10). A total of 103 operating units is included, and no known data on any unit have been excluded from the values herein reported. All the preceding factors are not known for each unit, but the number of units involved in the analysis of each performance factor is indicated.

In attempts at graphing various methods of presenting the field-experienced operating data shown in Figures 8, 9, and 10, it was found that reported values for these various units plotted a

as visible dust in the effluent gas. Efficiencies are all on a weight basis and in some cases were determined by simultaneous upstream and downstream sampling; in other cases the weight of dust collected in the filter during the sampling period was taken as the input loading. The median value with the last eight values excluded is 99.990%; with all values included, 99.977%.

Felt Treatments

Some few dusts exhibit a tendency to leak or seep through the felt. Although the leakage is not visible in the airborne state, it may in some cases be objectionable. The collection efficiency is not primarily a function of particle size, as is borne out by Table 1 and by some other experiences for which no quantitative data are available. This conclusion is not consistent with the many published tests and theoretical analyses of the relation of particle size to filtration efficiency, but it should be pointed out that such tests and analyses have not yet been performed for a dynamic equilibrium condition such as exists in the Hersey filter. It has been noted, for example, that ground limestone "Product G" (mass median 5.0μ, standard deviation 3.0) exhibits no detectable seepage, whereas ground limestone Quincy No. 2 (mass median 11μ, standard deviation 3.66) does, all other conditions remaining identical. Unfortunately, because of the nature of the experiment wherein this was noted, no quantitative efficiency data could be obtained.

The efficiency of the felt is improved by H.C.E. treatment, an impregnation with certain grades of silicones. The most complete investigation to date on the use of H.C.E. felt was made by Caplan and Mason (*6*) on a filter collecting radioactive dust less than 1μ in size and exhibiting seeping properties. They found that at the end of 110 days of service plain felt had an efficiency of 99.25%, whereas H.C.E. treated felt at the end of 158 days of service had an efficiency of 99.92%.

Self-Adjusting Blow Rings

The contact of the blow ring and the filter medium is of primary importance and is critical within narrow limits. Clean wool felt rubbed by smooth metal surfaces exhibits no appreciable wear in the absence of chemical attack or other adverse conditions, as proved by felt life of over 4 years on some early installations. Uniform conditions of felt contact are essential for long felt service. Wool felt, and probably any other material with similar filtering characteristics, is inherently dimensionally unstable. Consequently it was deemed advisable to provide self-adjusting rings (see Figure 11) so that a high degree of dimensional stability would not be required in such materials.

Pressure Control

It is not necessary to take the reverse-jet filter or a section of it offstream for cleaning the filter media. The porosity-restoring action takes place on each filter element as it is onstream filtering the dust-laden gases. Thus the filter resistance, always present as a pressure differential across the filter medium, can be used to actuate a pressure control. The pressure switch turns on the reverse-jet machinery when the resistance increases to a preset value and turns it off when the filter porosity has been restored, as indicated by decreased resistance. In this way the reverse jet is used when, and only when, it is needed, and the filter resistance is kept constant within the narrow differential limit of the switch. Thus the main gas flow, usually dependent on the resistance or pressure drop of the filter and other component parts of the system, may be kept essentially constant. Figure 12 shows a typical pressure recording for a unit on pressure control. The pressure rise takes place while the reverse jet is not operating, the sharp pressure decrease, while the reverse jet is on. The increased frequency of the saw-tooths indicates increased dust loading; the lower frequency, a lighter loading. A more detailed discussion is given by Hersey (*7*). Pressure-control operation usually results in the reverse jet operating about 10 to 20% of the total filter-operating time. If the reasonable assumption is made that maintenance of reverse-jet equipment and felt-tube replacement is proportional to operating time, pressure control is worth while from the maintenance viewpoint alone.

Redeposition and Its Control

Even though the filter ratios are usually satisfactorily high, Hersey (*7*) gives indications that they could be even higher if dust jetted off the filter medium could be prevented from redepositing on the filter. A new form of reverse-jet filter, of which three successful experimental models have been built, is shown in Figures 13 and 14. In this form the felt is supported on the outside

Table 1.—Collection-Efficiency Range of the Hersey Reverse-Jet Filter

Item No.	Nature	Inlet Load grains/cu.ft.	Particle Size Mass Median, μ	% Passed	% Collected	Reference
1	Radioactive	4.25×10^{-3}	...	0.0004	99.9996	(6)
2	Vaporized silica	1.07	0.6	0.00093	99.9991	(3)
3	Vaporized silica	1.26	0.6	0.0014	99.9986	(3)
4	Radioactive	32.4	....	0.0013	99.9987	(6)
5	Talc	0.14	1.25	0.0019	99.9981	(3)
6	Radioactive	14.0	....	0.0027	99.9973	(6)
7	Fly ash	11.2	....	0.0039	99.9961	(3)
8	Fly ash *	13.4	....	0.0046	99.9954	(3)
9	Radioactive	2.1×10^{-3}	....	0.0048	99.9952	(6)
10	Talc	0.2 to 6	1.25	0.005	99.995	(5)
11	Talc	0.16	1.25	0.0078	99.9922	(3)
12	Radioactive	0.39	....	0.0098	99.9902	(6)
13	Tapioca starch	3.17	7.7	0.01	99.99	(2)
14	Fly ash *	11.9	....	0.0114	99.9886	(3)
15	Radioactive	1.89	....	0.0146	99.9854	(6)
16	Fly ash *	1.12	....	0.023	99.977	(3)
17	Radioactive	0.202	....	0.0232	99.9768	(6)
18	Al_2O_3 (grinding wheel mfg.)	3.10	10.0	0.03	99.97	(2)
19	Al_2O_3 (grinding wheel mfg.)	2.26	7.2	0.04	99.96	(2)
20	Al_2O_3 (grinding wheel mfg.)	2.44	....	0.05	99.95	(2)
21	Radioactive	0.0456	....	0.0515	99.9485	(6)
22	Radioactive	0.418	....	0.054	99.946	(6)
23	Al_2O_3 (grinding wheel mfg.)	3.3	2.5	0.07	99.93	(2)
24	Fly ash *	1.24	....	0.082	99.918	(3)
25	Al_2O_3 (grinding wheel mfg.)	0.65	8.5	0.12	99.88	(2)
26	BeO crushing	0.14	....	0.37	99.63	(2)
27	BeO—SiO_2 founding	0.0054	....	0.41	99.59	(2)
28	Al_2O_3 (grinding wheel mfg.)	0.130	18.0	0.77	99.23	(2)
29	BeO crushing	0.029	....	1.97	98.03	(2)
30	Rouge polishing	0.0094	9.8	2.38	97.62	(2)
31	Rouge polishing	0.0048	1.2	2.49	97.51	(2)
32	B_4C	0.075	2.3	2.80	97.20	(2)

* Laboratory experiments at greater-than-normal reverse-jet velocities.

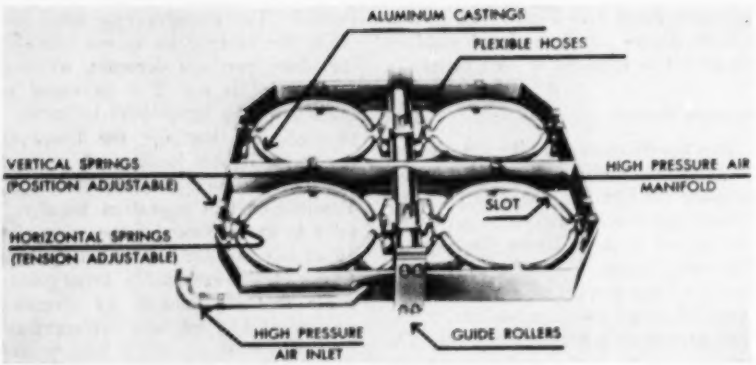

Fig. 11. Self-adjusting blow rings.

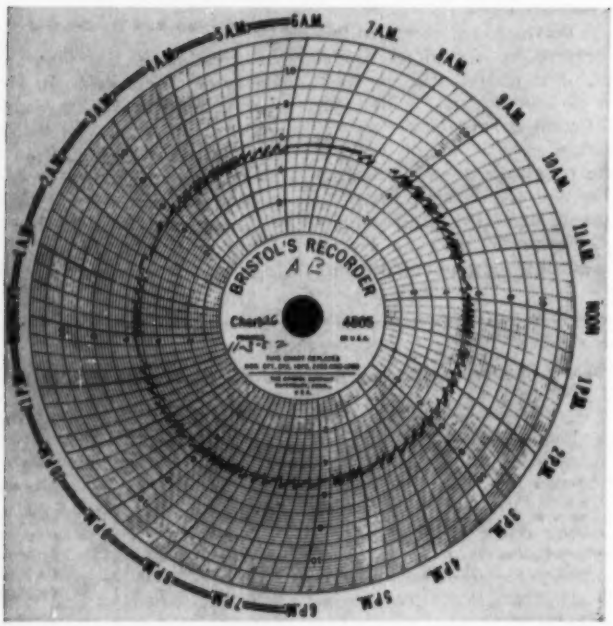

Fig. 12. Pressure recorder chart showing filter resistance of a unti on pressure control. Increased frequency of cycles indicates increased dust load. Chart calibrated in inches water gauge.

of a screen cylinder, the dusty side being outside. The screen support greatly reduces the mechanical strength and dimensional stability requirements of the filter medium. A straight blow tube, slotted on the outside, lies between the felt and the screen but does not touch the screen. As the blow tube is driven by the slow-turning central shaft, it describes a cylinder of revolution between the felt and the screen.

Mounted on the outside of the felt and driven by the same central shaft, is a channel-shaped member not visible in the photograph. It revolves with the blow tube, keeping pace with it and channeling the reverse-jetted dust downward to the collection hopper. This largely minimizes, if it does not completely prevent, redeposition. It is also possible to mount a wiper on this channel member, the need for which in some cases is also discussed by Hersey (*7*).

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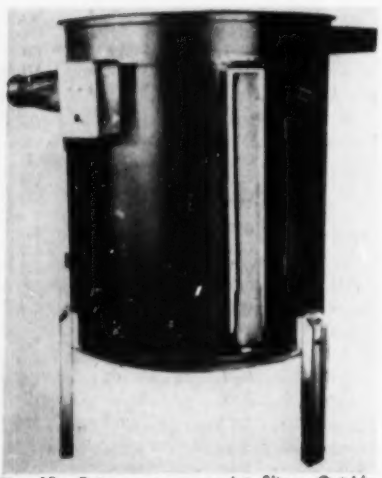

Fig. 13. Rotary-arm reverse-jet filter. Outside view without hopper.

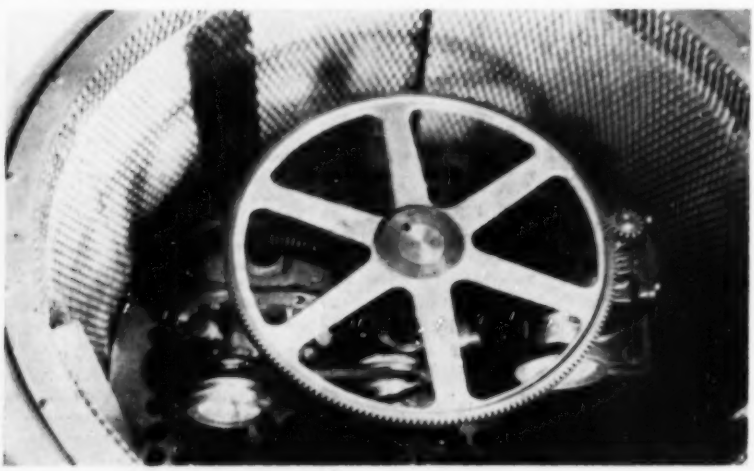

Fig. 14. Rotary-arm filter. Inside view from top.

process design of light hydrocarbon cracking units

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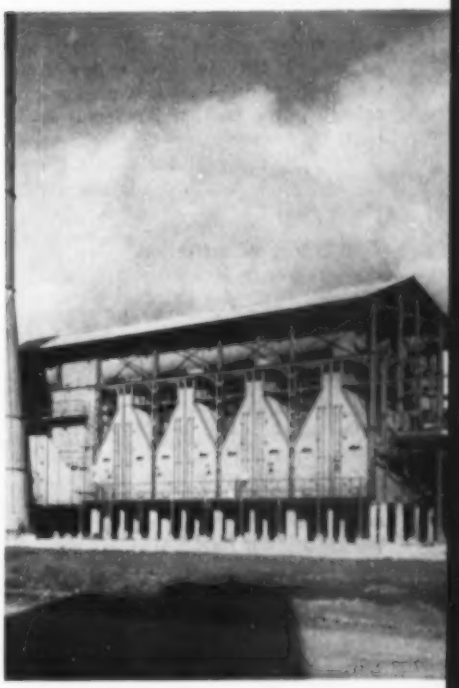

The art of thermal cracking, or pyrolysis, has been practiced in the petroleum and allied industries for many years. Charge stocks have ranged from complex mixtures such as gas oil and naphtha to simple compounds such as ethane and propane. Although much effort has been directed toward an understanding of the chemistry of cracking, the many complexities involved have precluded concrete deductions. In general the process engineer has been compelled to design pyrolysis units by a sort of educated speculation. A logical approach to the design problem must consider commercial practice as well as fundamental reaction kinetics. A design procedure combining these elements is presented in this paper, together with a complete process design calculation.

This paper will consider only charge stocks in the light hydrocarbon ($C_2 - C_4$) range. These charge stocks are of commercial importance because of the many chemicals that are derived from the olefinic cracked products. Other important commercial pyrolysis reactions exist, and it should be emphasized that design methods presented here may be extended outside the light hydrocarbon field.

Several types of commercial equipment are available for light hydrocarbon pyrolysis (*1, 2, 3, 4*), but by far the most common type is the direct-fired tubular heater. In this heater the reacting material is continuously conducted through several pipes (or tubes) connected in series, which are receiving radiant and convection heat from burning gas or oil. The number and arrangement of such tubes are set to produce the desired degree of conversion (usually at temperatures in the 1300-1500° F. range). The cracked gases leaving the heated zone are cooled rapidly, and pass to separating equipment.

The problem of designing a tubular pyrolysis unit is logically divided into two parts which, for want of better terminology, may be called the design of the coil and design of the furnace. The design of the coil consists of selecting the proper diameter and total length of tubes needed to produce the required conversion at some assumed heat flux. The design of the furnace includes selection of tube material, arrangement of the tubes, and the design of the convection and radiant sections. Since it has been covered adequately in the literature (*9, 11, 16*) and since design firms have developed competent heater departments for the purpose, the design of the furnace will not be considered here. The design of the coil, however, falls directly to the process engineer. Even if he is not charged with the original design of the coil, it will be his duty to predict the effect of changes in operating conditions and charge stocks.

The general aspects of light hydrocarbon cracking in tubular units were described adequately by Schutt (*18*) a few years ago. His data are quite reliable and will form an important part of the design procedure to be developed here.

Pyrolysis Rates

From a standpoint of kinetics, pyrolysis reactions are homogeneous, noncatalytic, and occur in the gas phase. Many investigations have shown that the paraffins decompose essentially along first-order lines; i.e., the rate of disappearance of a reactant is directly proportional to the amount of reactant remaining. Under the high temperature conditions of decomposition, it is quite likely that the reactions proceed through the formation of free radical chains. Rice and Herzfeld (*15*) have shown mathematically that when chain reactions involving free radicals are assumed, the paraffin disappearance is first order. From the standpoint of developing design methods, it is quite fortunate that this is so.

Studies of olefin decomposition have shown that the over-all rate of disappearance is not quite first order. This stems from the simultaneous decomposition and polymerization reactions which occur. The initial reactions are first order, however (*21, 22*), and since olefins are not generally present in large amount in the charge stocks, and, since their degree of conversion is relatively low, one may also assume their disappearance to be first order.

A wealth of cracking rate data has appeared in the literature during the past twenty-five years. Many are erroneous due to faulty analyses, extraneous catalytic effects, and use of improper residence time. Consistency of results has been noted only in the careful determinations of the initial reaction rates, and these of course must be modified to include the many secondary reactions which occur in commercial coils.

The effect of the secondary reactions is to lower the over-all activation energies. For example, Szwarc (*21*) has found that propylene has an activation

energy of 72.0 kcal. when being *decomposed* to the extent of ½%. The activation energy for propylene *polymerization*, however, is on the order of 30-35 kcal. Since both types of reactions occur simultaneously in a commercial coil, a design based on the higher energy would be unnecessarily conservative.

Table 1 lists selected values from which the velocity constant may be calculated by the familiar Arrhenius equation:

$$k_e = Ae^{-E/RT} \qquad (1)$$

where

E = energy of activation
A = frequency factor

Both laboratory and plant data are included. The plant data have been back-calculated from performance tests and include over-all effects. When available, they should be used. When laboratory data must be used, they should be analyzed for coverage of over-all effects, and the initial rate should be modified accordingly. A design based on a high activation energy may have a few surplus tubes, but this can be corrected in plant operation by, for example, raising the operating pressure or reducing the operating temperature.

Table 1.—Velocity Constant Data

Material	$\text{Log}_{10}A$	E, k/cal.	Source	Literature Cited
Ethane	15.0	70.0	Laboratory	(23)
	12.3	60.0	Plant	(18)
Propylene	13.0	72.0	Laboratory *	(21)
	7.45	40.0	Laboratory	(12)
	13.4	64.8	Plant	(18)
Propane	13.5	63.1	Laboratory	(23)
	12.6	59.1	Plant	(18)
n-Butene	12.7	60.1	Plant	(18)
Isobutene	12.7	67.0	Laboratory *	(22)
	12.0	56.0	Laboratory	(7)
n-Butane	12.7	58.7	Laboratory	(20)
Isobutane	13.9	63.5	Laboratory	(20)

* Initial rate only.

Design Equations

In the development of design equations it is convenient to consider a pure compound A being converted, with inerts, I, in the feed undergoing no change. Based on one mole of A entering the reactor, the fractional conversion, a_A, at any point in the reactor is

$$a_A = \text{v} - n_A \qquad (2)$$

where

n_A = moles of A present at any point in reactor/mole of A entering.

The rate of reaction is defined by

$$r = \frac{-dn_A}{V_R d\theta} = ka_A = \frac{k\pi n_A}{n_t} \qquad (3)$$

where

V_R = reactor volume
n_t = total moles present/mole of A entering
k = reaction velocity constant based on thermodynamic activities
θ = time
π = total pressure

for a first-order, irreversible decomposition occurring under conditions such that the gases behave ideally (such conditions prevailing in a pyrolysis coil). The reaction velocity constant k_e is based on reaction rate data correlated in terms of concentrations instead of activities. Design problems are much simplified by considering activities and using the velocity constant k. Most experimental data reported, however, are in terms of k_e, which it has been shown (5) can be converted to k (assuming ideal gases) by the expression $k = k_e/RT$. The total number of moles per mole of A entering n_t varies throughout the coil since cracking reactions produce a net increase in moles. This can be expressed by the relation

$$n_t = 1 + n_I + \delta_A \qquad (4)$$

where

n_I = moles of inerts/mole of A entering
δ = increase in number of moles/mole of A converted (expansion factor)

Experimental evidence shows the expansion factor, δ, to be generally constant for the more important hydrocarbons, and a function of a for the others. Values of δ are given in Table 2.

Combining (4) with (3) gives

$$r = \frac{k\pi(1-a_A)}{1+n_I+\delta a_A} \qquad (5)$$

For a flow reactor,

$$\frac{V_R}{F} = \int_{a_{A1}}^{a_{A2}} \frac{da_A}{r} \qquad (6)$$

which gives

$$\frac{V_R}{F} = \int_{a_{A1}}^{a_{A2}} \frac{[(1+n_I)+\delta a_A]da_A}{k\pi(1-a_A)} \qquad (7)$$

For a small increment of volume * one may consider k, δ, π constant. Then,

$$\frac{k\pi\Delta V_R}{F} = \int_{a_{A1}}^{a_{A2}} \frac{(1+n_I)da_A}{1-a_A} + \delta \int_{a_{A1}}^{a_{A2}} \frac{a_A da_A}{1-a_A} \qquad (7a)$$

which, when integrated between limits of a_{A2} and a_{A1}, gives

$$\frac{k\pi\Delta V_R}{F} = (1+n_I+\delta)\ \ln\frac{1-a_{A1}}{1-a_{A2}} - \delta(a_{A2}-a_{A1}) \qquad (8)$$

which is the basic equation for a stepwise analysis of the cracking coil. For facility in computation it is convenient to remove the logarithmic term from Equation (8). One may write

$$\ln\frac{1-a_{A1}}{1-a_{A2}} = \ln\left(1+\frac{\Delta a_A}{1-a_{A2}}\right)$$

* Experience will guide the designer in choosing the size of the increment. In general one or more tubes are used. The temperature change in zones of significant conversion should not be greater than 20-30° F./increment.

Table 2.—Expansion Factor

Material	Conversion Range, %	δ	Literature Cited
Ethane	0-65	0.92	(18)
Propylene	0-60	0.35	(18)
Propane	0-80	0.92	(18)
n-Butene	0-80	0.73	(18)
Isobutene	0-60	$0.25 + a$	(7, 14)
n-Butane	0-90	$1.00 + 0.30a$	(13, 19)
Isobutane	0-90	$1.00 + 0.30a$	(10, 19)

where $\Delta a_A = a_{A2} - a_{A1}$. When Δa is small, a series expansion of

$$\ln\left(1 + \frac{\Delta a_A}{1 - a_{A2}}\right)$$

yields

$$\ln \frac{1 - a_{A1}}{1 - a_{A2}} = \frac{\Delta a_A}{1 - a_{A2}}.$$

Thus, Equation (8) becomes

$$\frac{k\pi\Delta V_R}{F} = (1 + n_I + \delta)\frac{\Delta a_A}{1 - a_{A2}} - \delta_A \Delta a_A$$

$$= \frac{\Delta a_A}{1 - a_{A2}}(1 + n_I + \delta a_{A2}) \qquad (8a)$$

For example, for ethane cracking when no inerts are present in the charge, $n_I = 0$ and $\delta = 0.92$. Hence, the basic rate equation becomes

$$\frac{k\pi\Delta V_R}{F} = \Delta a_A \frac{1 + 0.92 a_{A2}}{1 - a_{A2}}. \qquad (9)$$

Calculation Procedure

With the basic equation established, it remains only for one to proceed through the coil using stepwise increments of volume. The computation procedure for a typical increment is as follows:

1. Assume the average gas temperature for the increment.
2. Assume the average gas pressure for the increment.
3. Obtain the value for the reaction velocity constant from a plot of k vs. temperature.
4. Calculate the incremental conversion $(a_{A_2} - a_{A_1}) = \Delta a_A$.
5. Check the assumed temperature by a heat balance over the increment. The coil designer will have at hand a value of the heat flux on the outside of the tubes; this will be the same value of flux used by the furnace designer. Of the total heat sent to the increment, a portion will go to endothermic cracking and the remainder to sensible heating of the gases.
6. Check the assumed pressure by a friction drop calculation.

In a similar fashion calculations are made throughout the length of the coil until the desired exit conversion is reached. When the calculations are completed, it may be found that the exit pressure is too low for subsequent processing equipment, or that the temperature is too high for the tube metal to withstand. In such cases it may be necessary to repeat the calculations until conditions are as desired.

Product distribution curves such as those given by Schutt (*18*) are used for both the analysis of the final cracked gas and for the compilation of physical properties of the gases at intermediate conversions. For example, heats of cracking are calculated for several different temperatures and then plotted against reactant conversion with temperature parameters. These steps will be clarified in the example problem.

Mixtures

The design Equation (8) or (8a) was developed for the case in which only one component of the feed undergoes decomposition. Often it is desirable to recycle certain cracked products in order to increase yields. This results in the cracking of a mixture. For mixtures the same basic equation is used, but additional preliminary work must be done. If a mixture of 75% propane and 25% propylene is being charged to the reactor, a set of product distribution curves must be prepared with separate curves for propane and propylene and with the technique described by Schutt (*18*). Then, the effects of temperature and conversion on heat of cracking, heat capacity, viscosity, molar expansion, etc., are computed and plotted. With these working charts at hand stepwise calculations are carried out through the coil with propane as the key reactant A and propylene as an inert. It must be remembered that δ_A may no longer be constant; however, its value never changes greatly with conversion, and Equation (8) may be used with periodic adjustment of the value of δ_A.

Whether one is dealing with pure materials or mixtures, the final step is always to obtain final product composition from the curves of Schutt or their equivalent.

Example Design

Calculation procedures such as those required for the design of a pyrolysis coil are best described by an example problem and its solution. Hougen and Watson (6) described the design of a benzene pyrolysis unit in such a manner, but only two simultaneous reactions were involved and calculations could be made with the aid of individual reaction rates. The following example will illustrate effectively the techniques involved when a number of indistinguishable reactions are involved.

It is desired to design a pyrolysis coil for processing 7,000 lb./hr. of a mixture containing 75 mole % propane and the remainder propylene. The furnace arrangement is such that the flow is in one continuous pass through a series of horizontal tubes connected by welded return bends. Only the design of the radiant zone will be considered; the charge enters this zone at 1,000° F. and 60 lb./sq.in.abs. after a preheating in a convection zone. The effluent from the radiant zone must be at a pressure no lower than 10 lb./sq.in.gauge, in order that flow may be maintained through downstream equipment. At this point the conversion of propane in the charge is to be 65%.

The radiant tubes are to be 4-in. I.P.S., Schedule 40, austenitic-type stainless steel, of 24 ft.-0 in. straight length and located on 12-in. centers. The maximum practical temperature for economically available alloys is about 1,500° F. Above this temperature even the austenitic stainless steels are subject to excessive deformation (creep) and oxidation. Hence, the effluent from the radiant zone should be no higher than 1,475° F. All tubes and return bends are to be exposed to a heat flux of 10,000 B.t.u./(hr.)(sq.ft.) outside surface.

General Comments

It may appear that the tube size, temperature, and pressure specifications impose too severe a restriction on the design calculations. As in many engineering design problems, however, it is necessary to start with certain assumed sizes. Preliminary calculations, not shown here, suggested the 4-in. tube size as a first approximation. It may prove too large or too small, in which case additional calculations for other sizes will be required.

It is assumed that the furnace design will allow convection-preheating of the charge to 1,000° F. The detailed calculations which follow will show that the radiant section design is not especially sensitive to the inlet temperature as long as it is below 1,200° F. (the "point of incipient cracking").

The exact specification on the stainless steel for tubes and return bends is not included since it is not pertinent to the problem at this point.

Working Charts

Prior to the start of design calculations it is desirable that certain working charts be prepared. Use of these charts reduces chances for error and assures a methodical solution of the problem. Working charts for the example problem are shown as Figures 1-5.

Figure 1 shows product distribution curves taken from the separate charts for propane and propylene presented by Schutt (*18*). Calculations for the mixture are on an additive basis, with relative rates of propane and propylene disappearance being taken from the velocity constant data of Table 1. Material balance calculations determined at several values of propane conversion (Figure 1) show that δ, the molar expansion factor, has an essentially constant value of 0.83 over the range of 0-65% conversion.

Material balances calculated from Figure 1, together with data on heat of formation (*17*), are used in the preparation of Figure 2. This chart presents heat of cracking as a function of conver-

sion. It should be noted that ordinate values are heats of cracking for the mixture based on propane converted.

Heat capacity of the reacting gases is shown on Figure 3. Material balance data from Figure 1 plus heat capacity data from Kobe, *et al.* (*8*), form the basis of the curves. It should be noted that the ordinate values are based on unreacted charge, which means that molar expansion is taken into account automatically.

Figure 4 presents data for calculating the pressure drop of the reacting gases. The curves are based on a modification of the Fanning equation and incorporate viscosity data obtained by the method of Uyehara and Watson (*24*). Material balance data from Figure 1 are used in the region of significant conversion.

Velocity constant values for Figure 5 have been taken from the plant data for propane in Table 1. Concentration units of reciprocal seconds have been converted to units readily applicable to the calculations.

Rate Equations

The basic rate equation used throughout the stepwise calculations has been developed:

$$\frac{k\pi\Delta V'_R}{F} = \frac{\Delta a_A}{1 - a_{A2}}(1 + n_I + \delta_A a_{A2}) \qquad (8a)$$

and in the region of incipient reaction, when a_A is small (<0.01), one may write

$$\frac{k\pi\Delta V'_R}{F} = (1 + n_I)\Delta a_A$$

Volume, cu.ft. (ΔV_R) 2.24
Heated surface, sq.ft. outside 30.0
Heat input, B.t.u./hr., (Δq)....300,000
Equivalent length, ft. (ΔL) 44.0

which completes the basic working data required.

Stepwise Calculations

INCREMENT 1

Assume:

Average temperature = 1,026° F.
Average pressure = 59.6 lb./sq.in.abs.

From Figure 5, $k = 2.0 \times 10^{-4}$ lb. moles/(hr.)(cu.ft.)(lb./sq.in.abs.)

By Equation (8b), $\Delta a_A =$

$$\frac{(2.0)(10^{-4})(59.6)(2.24)}{(120.7)(1.33)} = <<0.01$$

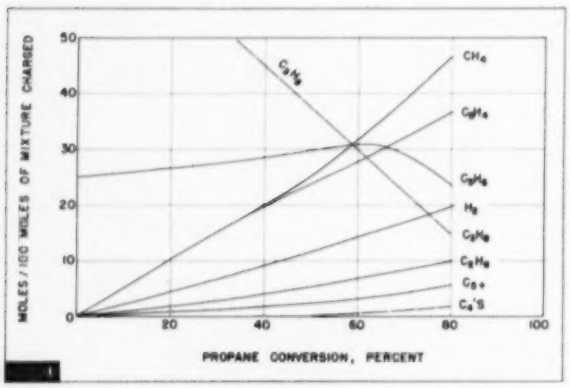

Fig. 1. Product distribution curves for 3 : 1 propane : propylene charge.

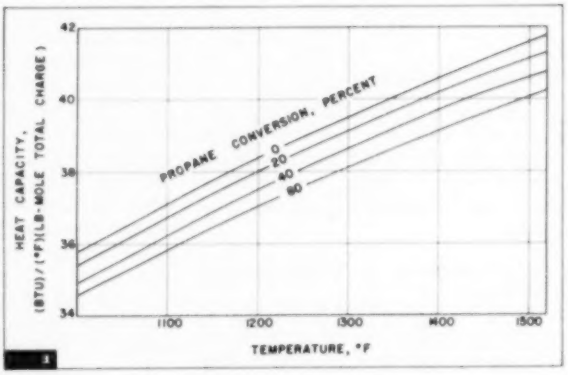

Fig. 3. Heat capacity for 3 : 1 propane : propylene charge.

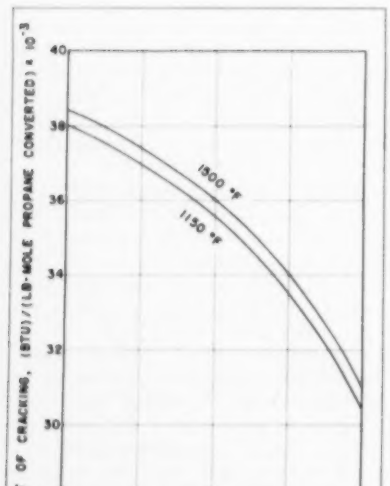

Fig. 2. Heat of cracking for 3 : 1 propane : propylene charge.

or

$$\Delta a_A = \frac{k\pi\Delta V'_R}{F(1 + n_I)} \qquad (8b)$$

The latter equation is convenient for *probing* the point of significant initial conversion, after which Equation (8*a*) is used. If $n_A = 1.0$ (propane) is considered, then $n_I = 0.25/0.75 = 0.33$ (propylene). $\delta_A = 0.83$ = constant as noted above. The total propane fed per hour, based on 43.5 mole wt. charge, is

$$\frac{(7{,}000)}{(43.5)}(0.75) =$$

$$120.7 \frac{\text{moles}}{\text{hour propane}} = F$$

The total feed is 7,000/43.5 =

$$160.9 \frac{\text{moles}}{\text{hour total feed}} = F'$$

If an increment equal to one tube plus a return bend is considered, the result is

Hence, there is no significant conversion, and only sensible heating needs to be considered. For this, the heat capacity is 36.1 B.t.u./(° F.) (lb. mole total feed) [Figure 3], and

$$\Delta t = \frac{\Delta q_s}{(C_p)(F')} = \frac{300{,}000}{(36.1)(160.9)} = 52° \text{ F.}$$

From Figure 4, the pressure drop factor is 1.04. Then,

$$\Delta\pi = \frac{(\text{Factor})(\Delta L)}{\pi} = \frac{1.04(44.0)}{59.6}$$

$$= 0.77 \text{ lb./sq.in.}$$

Summarizing, for increment 1,

Exit temperature, ° F. 1,052
Average temperature, ° F. 1,026
Exit pressure, lb./sq.in.abs. 59.2
Average pressure, lb./sq.in.abs. ... 59.6
Exit fractional conversion 0

INCREMENTS 2-4

As in increment 1, no significant conversion occurs.

Detailed results are summarized in Table 3. The gases emerge from increment 4 at the following conditions:

Temperature, ° F. 1,202
Pressure, lb./sq.in.abs. 56.7
Fractional conversion 0

INCREMENT 5

Assume:

Average temperature = 1,224° F.

Average pressure = 56.2 lb./sq.in.abs.

From Figure 5, k = 0.0125 lb. moles/(hr.)(cu. ft.)(lb./sq.in.abs.)

By Equation (8b), $\Delta a_A = \dfrac{(0.0125)(56.2)(2.24)}{(120.7)(1.33)}$

$= 0.010$

Heat of cracking, from Figure 2, is 38,000 B.t.u./lb. mole propane converted. Then, the total heat of cracking for the increment is

$\Delta q_R = (\Delta a_A)(\Delta H_R)(F)$

$= 0.01(38{,}000)(120.7) = 45{,}800$ B.t.u./hr.

The sensible heat is then calculated:

$\Delta q_s = \Delta q - \Delta q_R = 300{,}000 - 45{,}800$

$= 254{,}200$ B.t.u./hr.

The heat capacity from Figure 3 is 38.6 B.t.u./(° F.)(lb. mole total feed), and

$\Delta t = \dfrac{254{,}000}{(38.6)(160.9)} = 41°$ F.

From Figure 4, the pressure drop factor is 1.21. Then,

$\Delta\pi = \dfrac{(1.21)(44.0)}{56.2} = 0.95$ lb./sq.in.

Summarizing, for increment 5,

Exit temperature, °F. 1,243
Average temperature, ° F. 1,223
Exit pressure, lb./sq.in.abs. 55.7
Average pressure, lb./sq.in.abs. .. 56.2
Exit fractional conversion 0.01

INCREMENTS 6-20

The technique used for increment 5 is continued, with the exception that Equation (8a) replaces (8b) for the computation of the incremental change in conversion.

Results for each of these increments, together with supporting data, are presented in Table 3.

Final Results

Results are summarized graphically in Figure 6. Curves of this nature are quite useful for the prediction of the effect of changes in operating variables. The coil outlet conditions are:

Temperature, ° F. 1,469
Pressure, lb./sq.in.abs. 30.7
Conversion, % 71.7

and a total of 20 tubes is required.

It will be noted that the outlet conditions fulfill the requirement of minimum pressure, maximum temperature, and minimum conversion. The analysis of the effluent mixture may, if desired, be taken directly from Figure 1.

Notation

A = frequency factor in Arrhenius equation

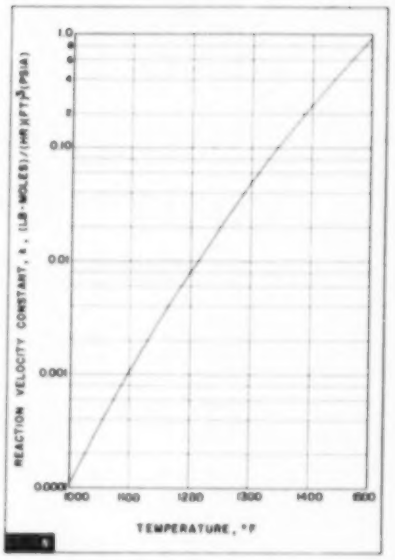

Fig. 5. Reaction velocity constant for propane.

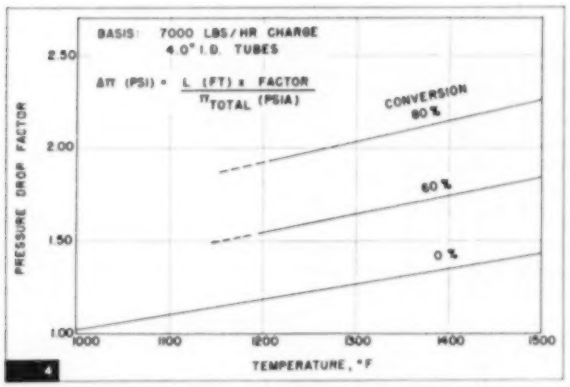

Fig. 4. Pressure drop factor for 3 : 1 propane : propylene charge.

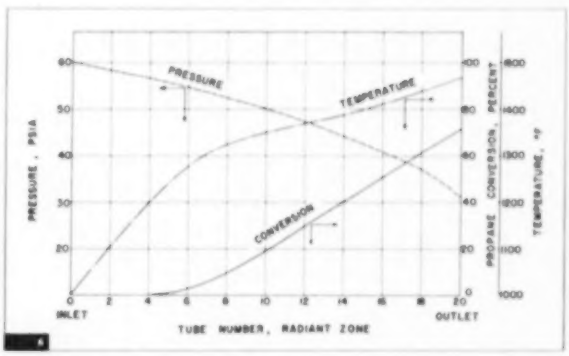

Fig. 6. Coil analysis curves for 3 : 1 propane : propylene charge.

α = thermodynamic activity
c_p = heat capacity at constant pressure, B.t.u./(lb.-mole)(° F.)
E = energy of activation, kcal.
F = feed rate of key reactant, lb.-moles/hr.
F' = total feed rate, lb.-moles/hr.
ΔH_R = heat of cracking, B.t.u./lb.-mole
k = reaction velocity constant based on thermodynamic activities
k_c = reaction velocity constant based on concentration units
L = coil length, ft.
ΔL = length of one increment
n = number of moles
q = quantity of heat added, B.t.u./hr.
Δq_s = sensible heat for one increment
Δq_R = heat of cracking for one increment
R = universal gas constant
r = reaction rate, lb.-moles/(hr.)(cu.ft.) reactor volume
T = absolute temperature
t = temperature, ° F.
Δt = temperature change for one increment
V_R = reactor volume, cu.ft.
ΔV_R = volume of one increment

GREEK LETTERS

α = fractional conversion
$\Delta\alpha$ = fractional conversion for one increment
δ = molar expansion factor, moles expansion/mole converted
π = total pressure, lb./sq.in.abs.
$\Delta\pi$ = pressure drop for one increment
θ = time, hr.

SUBSCRIPTS

A = key reactant
I = inert material
t = total

Table 3.—Summary of Stepwise Calculations

Increment Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
t_v, ° F.	1000	1052	1103	1153	1202	1243	1278	1305	1324	1339	1351	1361	1370	1380	1390	1401	1412	1425	1439	1453
π_v, lb./sq.in.abs.	60.0	59.2	58.4	57.6	56.7	55.7	54.7	53.7	52.6	51.4	50.1	48.8	47.5	46.0	44.4	42.7	41.0	39.1	37.1	34.6
a_i	0	0	0	0	0	0.010	0.028	0.055	0.095	0.140	0.190	0.243	0.297	0.351	0.405	0.459	0.513	0.564	0.615	0.667
t_{eve} (assumed), ° F.	1026	1077	1128	1177	1224	1262	1294	1316	1331	1344	1356	1365	1374	1384	1395	1407	1418	1432	1446	1461
π_{eve} (assumed), lb./sq.in.abs.	59.6	58.8	58.0	57.1	56.2	55.2	54.2	53.1	52.0	50.8	49.5	48.2	46.7	45.22	43.5	41.8	40.1	38.2	36.0	33.3
k_v, moles/(hr.)(cu.ft.)-lb./sq.in.abs. (Fig. 5)	0.0002	0.00063	0.00192	0.00500	0.0125	0.0245	0.043	0.062	0.080	0.098	0.118	0.135	0.156	0.180	0.212	0.250	0.286	0.360	0.440	0.550
Δa (assumed)	0	0	0	0	0.01	0.018	0.028	0.040	0.045	0.050	0.053	0.054	0.054	0.054	0.054	0.054	0.051	0.051	0.052	0.050
a_j	0	0	0	0	0.01	0.028	0.056	0.096	0.140	0.190	0.243	0.297	0.351	0.405	0.459	0.513	0.564	0.615	0.667	0.717
Left side, Eq. 8a	.....	.....	.....	.....	.....	0.0251	0.0432	0.0612	0.0772	0.0923	0.108	0.121	0.136	0.151	0.172	0.195	0.213	0.244	0.294	0.340
Right side, Eq. 8a	.....	.....	.....	.....	.....	0.0251	0.0412	0.0610	0.0760	0.0922	0.108	0.122	0.135	0.151	0.172	0.194	0.213	0.244	0.294	0.340
a_{ij}, corrected	0	0	0	0	0.01	0.028	0.056	0.095	0.140	0.190	0.243	0.297	0.351	0.405	0.459	0.513	0.564	0.615	0.667	0.717
Ht. cracking, $\times 10^{-3}$ B.t.u./lb. mole (Fig. 2)	.....	.....	.....	.....	38.0	38.0	38.0	37.8	37.6	37.4	37.1	36.7	36.4	36.1	35.7	35.2	34.7	34.1	33.6	32.5
Total ht. cracking $\times 10^{-3}$ B.t.u./hr.	.....	.....	.....	.....	45.8	82.5	128	178	205	226	237	240	237	237	232	229	214	210	210	196
Sensible heat $\times 10^{-3}$ B.t.u./hr.	300	300	300	300	234.2	217.5	172	122	95	74	63	60	63	63	68	71	86	90	90	104
Heat capcity, B.t.u./(° F.)(mole)(Fig. 3)	36.1	36.8	37.5	38.1	38.6	39.0	39.4	39.5	39.6	39.6	39.6	39.7	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.7
Δt (calc.), ° F.	52	51	50	49	41	35	27	19	15	12	10	9	10	10	11	11	13	14	14	16
t_{eve} (calc.), ° F.	1026	1078	1128	1178	1223	1261	1292	1315	1332	1345	1356	1366	1375	1385	1395	1407	1419	1432	1446	1461
$\Delta\pi$ factor (Fig. 4)	1.04	1.09	1.13	1.17	1.21	1.25	1.29	1.34	1.39	1.44	1.46	1.50	1.55	1.64	1.66	1.68	1.69	1.75	1.90	1.99
$\Delta\pi$ (calc.), lb./sq.in.	0.77	0.81	0.86	0.90	0.95	1.00	1.05	1.11	1.18	1.24	1.30	1.37	1.46	1.60	1.68	1.77	1.85	2.02	2.30	2.62
π_{eve} (calc.), lb./sq.in.abs.	59.6	58.8	58.0	57.1	56.2	55.2	54.2	53.1	52.0	50.8	49.5	48.1	46.7	45.2	43.6	41.8	40.0	38.1	35.9	33.3
Exit temperature, ° F.	1052	1103	1153	1202	1243	1278	1305	1324	1339	1351	1361	1370	1380	1390	1401	1412	1425	1439	1453	1469
Exit pressure, lb./sq.in.abs.	59.2	58.4	57.6	56.7	55.7	54.7	53.7	52.6	51.4	50.1	48.8	47.5	46.0	44.4	42.7	41.0	39.1	37.1	34.6	30.7
Exit conversion	0	0	0	0	0.010	0.028	0.056	0.095	0.140	0.190	0.243	0.297	0.351	0.405	0.459	0.513	0.564	0.615	0.667	0.717

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Illustration on the first page of this article shows a large commercial cracking unit (courtesy of The Lummus Co.).

CORRECTION

In the article on UREA in the July issue, page 328, it was erroneously stated that the Sumitomo Chemical Co. plant at Niihama, Japan, was designed to produce 12 tons/day of urea. This should have read 120 tons. In the Discussion on page 331 the correct figure is given.

Fig. 1. One-piece type Monel demister element, 6 in. thick, 48 in. in diam.

performance of wire-mesh demisters

Otto H. York | Otto H. York Co., Inc., West Orange, New Jersey

A wire-mesh demister consists of a knitted wire mat mounted on a light-weight support grid. The wire mesh most commonly used is fabricated with 0.011-in. wire to a density of approximately 12 lb./cu. ft. and has a surface area of 110 sq. ft./cu. ft. Entrainment separation efficiencies more than 99.9 wt. % are obtained over a wide range of vapor velocities. By increasing the impingement targets, residual entrainment can be reduced to as low as one part of liquid/10 billion parts of vapor by weight. Pressure drop in the usual type of installation is extremely low and rarely exceeds one inch of water gauge. Wire-mesh demisters permit operation at vapor velocities which would otherwise be excessive.

Various improvements in the operation of process equipment result. These include the elimination of liquid overhead losses, or the increase in quality of overhead product. Case histories for chemical plant and oil refinery installations are presented.

In the design of process vessels handling both liquid and gas phases, it is customary to calculate the tower diameter from the allowable vapor velocity, which is calculated from the equation:

$$U = K\sqrt{\frac{\rho_l - \rho_g}{\rho_g}}$$

where

U = superficial velocity, ft./sec.
ρ_l = liquid density, lb./cu.ft.
ρ_g = vapor density, lb./cu.ft.

K is a constant ranging from 0.04 for 6-in. plate spacing to 0.205 for 36-in. spacing.

With correct bubble-cap and liquid downcomer design, liquid entrainment becomes the limiting condition; means for entrainment control are then required to permit operation at the higher, more economical vapor velocities.

In some processes substantially complete entrainment separation may be required without regard to operating velocities. In vacuum towers producing gas oil for use as feed to catalytic cracking units, the liquid entrainment carries two objectionable materials: asphaltic bodies and catalyst contaminating metal impurities. In ethanolamine and glycol contactors entrainment results in direct loss of valuable materials. In gas absorbers entrainment of absorption oil decreases the desiccant life in solid-bed dehydration towers. In evaporator systems entrainment may cause fouling of condenser tubes thereby decreasing heat transfer. In vacuum evaporators entrainment frequently means direct loss of product through the barometric condenser. In atomic-energy installations complete separation of entrained radioactive solutions is required to prevent radioactive contamination.

Experimental studies and actual plant installations prove that the entrainment problems mentioned can be controlled with wire-mesh demisters, even at vapor velocities well above the allowable velocity as calculated by the established equation.

Description of Wire-Mesh Demisters

A complete wire-mesh demister consists of a suitably designed knitted wire-mesh mat supported on a light-weight grid. For any particular application the wire diameter is selected by giving proper consideration to separation efficiency and mechanical strength requirements, and cost. Various characteristics of wire mesh can be selected to fall within the following ranges:

Wire diameter	0.003 in. to 0.016 in.
Free volume	.92 to 99.4%
Density, lb./cu.ft.	.3 to 33
Surface area, sq.ft./cu.ft.	50 to 600

A commonly used demister mesh is made with 0.011-in. diam. wire to a free volume of 97.7%; in 18-8 stainless steel the density is approximately 12 lb./cu.ft., with a surface area of approximately 110 sq.ft./cu.ft. A demister assembly consisting of a 4-in. thickness of this wire mesh mounted on a light weight support grid has a weight of approximately 5.6 lb./sq.ft. The static liquid holdup (water) is approximately 10% based on the weight of the wire mesh, or less than 2% of the demister volume.

To obtain very high separation efficiencies,

the wire diameter is decreased and the density and thickness are increased.

For smaller vessels where the installation of a complete circular demister in a one-piece assembly can be made through the end opening of the equipment, the element is constructed by rolling the wire mesh upon itself to the desired diameter. These elements are usually 6 in. thick and are generally limited to about a 48-in. diam. A Monel element is shown in Figure 1.

Fig. 2. Sectional-type stainless steel diameter, 4-in. thick wire mesh on support grid sections, with removable manway section.

For larger vessels and for all applications where installation is to be made through a manhole, the sectional-type demister is used. Provisions can be made for downcomers, pipes, removable manways, etc. Figure 2 shows a 4-in. thick demister with grid for a 7-ft. 0-in. I.D. tower with a removable manway section in the demister.

Description of Operation

The separation action is that of impingement. A liquid particle strikes the wire surface and is momentarily held there. However, the smooth convex surface of the wire does not present the type of surface which easily remains wetted, with the result that the liquid drop almost immediately flows downward along the wire surface to a point where the adjacent wires provide capillary space. These spaces may be considered gathering stations for the liquid. In operation each wire crossing becomes rapidly overloaded, with the result that definite downward liquid flow patterns occur.

A 6-in. diam. transparent bubble-cap column was set up to demonstrate the separation action. The action obtained with a vapor velocity of 10 ft./sec. is shown in Figure 3. A full stream of collected liquid can be seen returning from the demister element. The experimental equipment with no vapor flow at the conclusion of the test is shown in Figure 4.

Allowable Vapor Velocities

In the operation of a wire-mesh demister three different forces are in action. The velocity force of the vapor tends to carry the liquid drop upward; impingement stops the upward motion of the particle, coalescing occurs, and the force of gravity tends to pull the now larger drop down; the third force is that of surface tension, which is not important except at the lower surface of the demister element. Here surface tension holds the liquid until drops are formed which are large enough so that the force of gravity exceeds the combined force of velocity and surface tension with the result that the large drop is torn away from the wire-mesh surface. These drops are then of sufficient size so that they will continue to fall against any reasonable velocity.

Referring again to the established velocity equation: the K values as shown in Table A will apply to free-flowing entrained liquids being separated by a standard 12 lb./cu.ft. wire-mesh demister.

Table A.

Disengaging Height (in.)	Allowable K Value
3	0.12
4	0.15
5	0.19
6	0.22
7	0.25
8	0.29
9	0.32
10	0.35
11	0.38
12	0.40
13	0.42
14	0.43

Efficiency

C. L. Carpenter (*1*) conducted extensive studies on entrainment separation efficiency in an evaporator which operated with salt solution under a variety of operation conditions. Separation efficiencies more than 99.9% were obtained over a wide range of operating velocities.

The efficiency curve shown in Figure 5 has been derived from a large number of test data on various different types of conventional process equipment.

In the separation of hydrocarbon liquids from natural gas wire-mesh demisters are designed and fabricated to meet a guarantee that not more than 0.1 gal. of liquid will remain per million actual cubic feet of effluent gas.

In the separation of radioactive solutions from vapors a high degree of separation efficiency is required. The original requirement of residual entrainment not to exceed one part per 10 million parts of vapor by weight was increased to one part per billion and then to one part per 10 billion parts of vapor by weight. This is accomplished by the use of a 3-ft. thick bed of high density wire mesh made with a fine diameter wire. Liquid wash is added to produce a dilution effect.

Pressure Drop

In nearly all applications the pressure drop through a wire-mesh demister is so low that it can be considered negligible for all practical purposes. In the usual operating ranges the pressure drop rarely exceeds 1-in. water gauge. Experimental data are given in Figure 6.

Installation Details

Since wire mesh is not a rigid material, it must be supported on suitable grids. To obtain minimum pressure drop, maximum throughput, and maximum efficiency, the support grids must have high per cent of free passage. In order to take full advantage of the approximately 98% free volume in the wire mesh, the free passage through the support grids should not be much below 90% (Figure 7). If the free

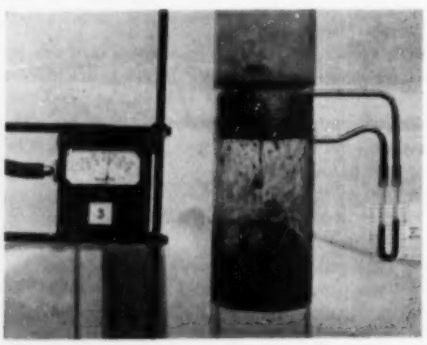

Fig. 3. At 10 ft./sec. air velocity there is no visible entrainment carry over through the demister.

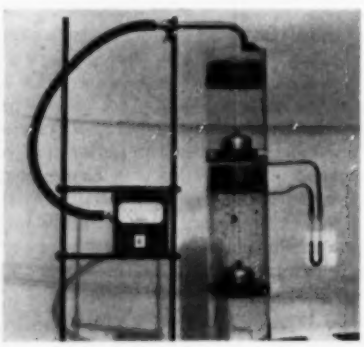

Fig. 4. At the conclusion of the test the water on the upper tray is entirely clear; there is no detectable evidence of colored liquid carry over from the tray below.

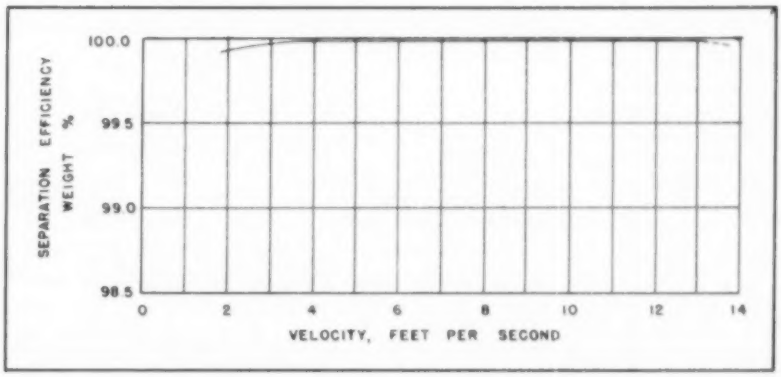

Fig. 5. Liquid entrainment separation efficiency from air or steam of a 4 in. thick, 12 lb./cu.ft. demister at standard temperature and pressure.

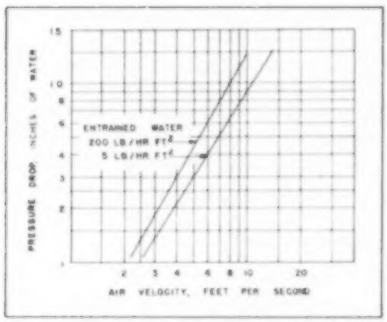

Fig. 6. Pressure drop for a 4 in. thick, 12 lb./cu.ft. wire-mesh demister at standard conditions.

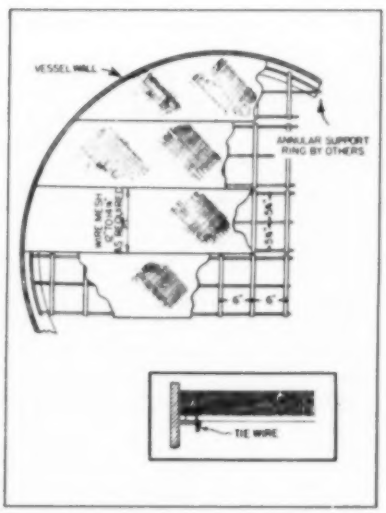

Fig. 7. Open-type support grid sections do not restrict liquid returning against vapor flow.

passage through the support grid is appreciably below this figure, the accumulated liquid will be prevented from draining back through the support grid and improper operation will result. Conventional steel grating or expanded metal are not suitable supports for wire-mesh demister elements, and in specific instances a switch to light-weight support grids changed an unsatisfactory installation into a successful one.

The installation of wire-mesh demisters is a relatively simple procedure and the cost of installation is low. The total labor to install a 12-ft. diam. demister should not exceed 40 man-hours.

Since the wire-mesh material is resilient a good fit between the adjacent demister sections and between the demister sections and the vessel wall is obtained without difficulty. It is of course necessary to make sure that no gaps remain if a high degree of separation efficiency is required.

The demister assembly consisting of the wire mesh and grid sections is usually mounted on an annular support ring. In those applications where it is necessary to anchor down the demister to provide against sudden velocity increases, it has been found that tying the demister sections with approximately 0.05-in. diam. wire usually provides a fully satisfactory installation. Bolting or other elaborate methods for securing the demister are usually unnecessary.

Economic Considerations

Demister costs will vary depending upon size, shape, and material of construction. The total cost of a complete demister, including grids for a total capacity of 50,000 cu.ft./min. constructed entirely of 18-8 stainless steel or Monel metal, will average $24.00/(1,000 cu.ft.)(min). The operation is fully automatic with no instrumentation required; operating and maintenance costs are so low they can be considered negligible. There are no moving parts, and high separation efficiency is obtained over a wide range of velocities.

Typical Applications

GLYCOL ABSORBER

In a gasoline plant a 15-in. diam. separator vessel was located in the 8-in. gas exit line from the top of a glycol absorber. Because of inadequate entrainment recovery the vane-type mist extractor element was removed and a wire-mesh demister element constructed of 18-8 stainless steel was installed at a total cost of $317. Tests were made which showed an additional recovery of 4.9 gal./day of 96% by weight triethylene glycol solution. At a cost of $2.25/gal. the entire installation was paid for in twenty-nine days.

COMPRESSOR SUCTION KNOCK-OUT

The maintenance of the compressors on a catalytic cracking unit was excessive. It was impossible to get proper lubrication in the cylinders and the valves would last thirty days or less. Investigation showed the source of trouble to be in the suction line from the receiver to the compressor. Heavy gasoline which could not be vaporized in the suction heater entered this line and carried into the compressors. Lube oil would be diluted and valve surfaces coated with a soft cakelike material.

To correct this operating difficulty a Monel metal demister 2 ft.-8 in. × 1 ft.-10½ in. × 12 in. thick mounted on a Monel light-weight grid was installed on the suction side of the compressors. The entrained liquid was removed and drawn off. After this demister was installed, the compressors ran longer than one year without extra maintenance.

PACKED COLUMN

In a 4-ft. diam. packed column used for scrubbing organic material from steam by circulating caustic solution on the packing, a steam rate of 3,000 lb./hr. gave rise to a finely divided caustic spray in the steam from the open top of the tower. The installation of a 6-in. thick demister entirely eliminated any objectionable caustic spray upon the surrounding area. This installation has given over three years' satisfactory operation with no maintenance costs.

VACUUM ASPHALT TOWER

The experience of the Sinclair Refining Co.'s Marcus Hook refinery is reported by H. S. Fourer (2). The vacuum tower is shown in Figure 8. The demister installation has made possible an increase in the feed capacity by 30 to 35%, with the same per cent overhead yield, and the maintenance of gas-oil quality. Some results are shown in Table B.

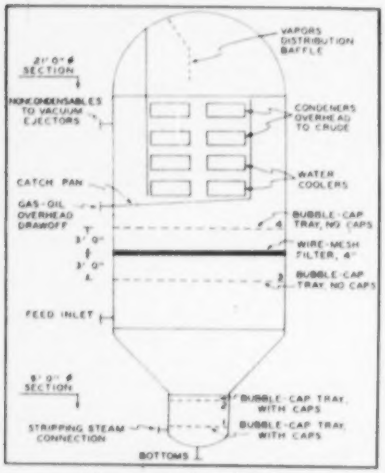

Fig. 8. Demister location in a 21-ft. diam. reduced crude vacuum tower.

Table B.—Demister Pad Installations

	Before Installation	After Installation
Feed, bbl. day	20,000	26,500
Superficial vapor velocity, ft./sec.	4.5	10.6
Gas-oil carbon residue, wt. %	0.51	0.38
Asphalt penetration	380+	300

VACUUM TOWER

The application of a wire-mesh demister to effect a reduction in metals contamination of gas oils is described by D. H. Stormont (3). A 17-ft.-8-in. diam. tower, taking a topped crude feed of 35,000 to 40,000 bbl. or more daily, delivers 60% bottoms, 10% side draw, and 30% overhead products. A wire-mesh demister blanket was installed to reduce catalyst poisoning by poor quality gas oil feed to the Thermofor Catalytic Cracking unit. A comparison of metals content before and after installation is shown in Table C.

LUBE OIL TOWER

A demister was installed in an 18-ft.-6-in. diam. vacuum tower charging approximately 25,000 bbl./day of reduced crude and producing overhead and sidedraw lube distillate cuts. Total demister installation cost was approximately $5,000. Three different benefits were obtained:

1. The improved quality of lube distillate reduced quite considerably the cost of subsequent processing, including clay treating.

Table C.

	(p.p.m.) Sidedraw Stream			Overhead Stream		
	Vanadium	Nickel	Ash	Vanadium	Nickel	Ash
Before blanket installed (11/28/51)	30	28	136	2.0	2.0	18
Blanket in place (4/22/52)	3	3	9.6	0.09	0.03	4.3
Blanket used 1 year (4/23/53)	3.5	3.5	36	0.16	0.17	6.3

2. An increase in throughput rate of approximately 20% was obtained, still maintaining high product quality.
3. A lower cost reduced crude, previously unusable because of extremely bad color, could now be used.

Detailed figures are not available but summary calculations for this installation show a net annual saving of approximately $1,000,000.

Caustic Evaporator

A serious entrainment problem existed in the 10-ft., 6-in. diam. vapor disengaging head of a forced circulation type of caustic soda evaporator operating at 70,000 lb./hr. at 190° F. and 22-in. Hg vacuum. A specially designed 12-in. thick high efficiency nickel wire-mesh demister was installed and the entrainment was reduced to a figure well below the guaranteed 6 p.p.m. maximum.

Compressor Suction Drum

Considerable maintenance difficulties were being experienced in propane compressors, probably due to water entrainment in the compressor intake. A 6-in. thick wire-mesh demister was installed in the 4-ft.-6-in. diam. knockout drum ahead of the compressors. During six months of operation, the following results were noted:

(a) No scale has formed on the compressor valves, whereas previous to the installations, scale had formed rapidly.

(b) Compressor valve maintenance has been sharply reduced (40%), and it has been decided that remaining maintenance is not due to entrainment.

(c) A centrifugal separator, installed downstream from wire-mesh demister at the same time the wire-mesh demister was installed, has collected no entrainment.

(d) Pressure drop through the wire-mesh demister has been less than ½ in. of water.

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1. Carpenter, C. L., D.Ch.E. Dissertation, Polytechnic Institute of Brooklyn (1951).
2. Fourer, H. S., *Oil Gas J.*, **52**, No. 25, 86-7 (1953).
3. Stormont, D. H., *Oil Gas J.*, **52**, No. 25, 87, 121-22 (1953).

Presented at A.I.Ch.E. Washington, D. C., meeting.

CORRECTION

In "Distillation Control Problems—Application of the McCabe-Thiele Diagram" (C.E.P., June, 1954, page 312), authored by R. L. Bauer and C. P. Orr, Table 1, on page 313, has been corrected to the values shown below in light face. Old values, now incorrect, are shown in bold face.

Also on page 313 under Control Systems Studied, c. should read as follows: 'Composition control of the liquid on a plate in the stripping section by varying the amount of boilup [not holdup].

Table 1

Case	z_F	x_D	x_W	D	W	L	V	L'	V'
				0.372	**0.628**	**0.618**	**0.990**	**1.618**	**0.990**
5	0.400			0.371	0.629	0.615	0.986	1.615	0.986
				0.024	**0.976**		**1.255**		**1.255**
6	0.020			0.023	0.977		1.254		1.254
		0.389	**0.0007**	**0.024**	**0.976**		**1.255**		**1.255**
7	0.010	0.393	0.0008	0.023	0.977		1.254		1.254
				0.024	**0.976**		**1.255**		**1.255**
	0.040			0.023	0.977		1.254		1.254
			0.0013	**0.012**	**0.988**		**1.255**		**1.255**
8	0.010		0.0019	0.011	0.989		1.254		1.254
						1.205	**1.255**	**2.205**	**1.255**
	0.040					1.204	1.254	2.204	1.254

catalytic oxidation of aqueous wastes

John Oliver

E. I. du Pont de Nemours and Company, Charleston, West Virginia

This paper covers operating experience with a catalytic oxidation unit installed to dispose of aqueous waste materials obtained from an ethylene glycol synthesis operation.

The ethylene glycol synthesis process produces quantities of dilute organic aqueous wastes which cannot be recovered in available process equipment. Further, the concentration of organics in the waste streams is insufficient to support combustion of the organics with air without the use of additional fuel, the installation of large heat exchangers, or the use of a catalyst which will achieve the desired level of oxidation at a relatively low temperature. To meet this waste-destruction problem a catalytic oxidation unit, originally developed as part of a plant-wide program to reduce river pollution (*1*) was considered.

The economics of disposing of wastes by the catalytic process was compared with three other methods which were considered possible competitors: (1) recovery of the organic material by the installation of additional process equipment, (2) recirculation of the waste streams for additional recovery in existing process equipment, and (3) simple combustion of the waste streams by use of additional fuel in order to reach the required oxidation temperature. As a result of this comparison the catalytic oxidation process was installed.

Figure 1 gives the analyses of the waste streams along with approximate heating values. The commercial equipment was designed to handle 15,000 lb./hr. of waste stream A containing 5.3% organics and having a heating value of 220 p.c.u. (pound centigrade unit)/lb. and 4,000 lb./hr. of waste stream B containing 15% organics and having a heating value of 910 p.c.u./lb. These two waste streams represent a river pollution load of 32,100 lb./day of biological oxygen demand (B.O.D.).

Figure 2 is a diagram of the process equipment provided in the commercial installation. The important equipment pieces are the air blower, the heat ex-

WASTE STREAM "A"		WASTE STREAM "B"	
QUANTITY	15,000 LB/HR	QUANTITY	4,000 LB/HR
ORGANICS	5.3%	ORGANICS	15%
FORMALDEHYDE		HIGHER ALCOHOLS	
METHANOL			
MONOBASIC ACIDS			
WATER	94.7%	WATER	85%
HEATING VALUE	220 PCU PER LB	HEATING VALUE	910 PCU PER LB

Fig. 1.

change surface, and the converter containing the catalyst. This is the equipment used in normal operation to obtain oxidation of the wastes. The other equipment is employed for reaching the initial ignition temperature or for providing temperature control during operation. The piping represented by the dashed lines was added after start-up to obtain the desired operating performance and will be described in greater detail later.

The converter containing the catalyst bed is the only piece of equipment designed specifically for this waste-oxidation system. The principal features are shown in Figure 3. The crosshatched areas indicate insulation of either fire brick or the cast variety. No weaknesses have been encountered in the design, and it has come through one serious overheating experience with damage only to the catalyst support trays, which are easily replaced.

A brief description of the start-up procedure and normal operating control follows. Waste stream A is in the vaporized state and comes to the oxidation unit from an existing distillation column. Before the catalytic oxidation unit was installed, this stream was condensed and discharged to the river. Waste stream B is supplied to the oxidation unit in liquid form and is vaporized in a steam-heated vaporizer.

In a normal start-up (Figure 2) the air blower is started and part of the air flow is heated to 150° C. in the steam-heated preheater and then to 250° C. in the electric preheater. When these temperatures are reached and the pilot converter catalyst has been heated to 200° to 250° C., a small quantity of waste stream B is introduced. For obvious reasons waste B, containing the higher concentration of organics, is normally used for the start-up operation. Reaction begins immediately in the pilot converter, and the exit gas at 550° C. provides the necessary heat to preheat the main converter to 250° C. to obtain ignition of the main gas stream. At this point the main line valve L is opened and the process is in operation. To level the unit for normal operation, the air and waste stream flows are increased to the desired level. In order to maintain the desired reaction temperatures, shown in Figure 2, the heat-exchanger by-pass valves and the dilution-steam-admission valve are adjusted as the concentration of organics in the waste streams (and consequently the heating value of the streams) varies. The hot gas stream containing primarily CO_2, H_2O, O_2, and N_2 passes through the heat exchanger for recovery of heat and is then discharged to the atmosphere. There has been no atmospheric pollution problem.

On the basis of the original experimental data, it was expected that 99+% combustion of the organics in the waste streams would be obtained with a feed temperature of 300° C. while a copper chromite catalyst was used. Copper chromite was selected after four different catalysts were tested, because it performed as well as others and is a spent hydrogenation catalyst available from another step in the process.

Discussion

Shortly after start-up of the commercial unit a few revisions were found necessary in order to obtain stable operation. With these changes, the unit disposes of the expected quantity of wastes with a cleanup of about 97%. The unconverted 3% has given no problem as an air pollutant, as it is sufficiently vaporized and dispersed to be undetectable. In retrospect, the author would install the same facilities to dispose of organic wastes of the concentration and character encountered in this process if the same problem were faced today. In fact, a second unit is being designed to dispose of a similar waste stream from the ethylene glycol process.

The first difficulties encountered during start-up concerned the combination steam and electric preheaters provided to reach ignition temperature in the pilot converter. During initial operation neither the steam nor electric preheaters provided the degree of preheat expected of them. The difficulty was remedied by providing a spacer in the electric preheater which increased the velocity of the gases over the heated surfaces. The problem could have been solved by modifying the steam-heated preheater, but the solution used was the less expensive one.

As soon as the preheater problem was solved and initial lightoff was accomplished, difficulties were encountered with temperature control in the main converter. The first step in the solution of this problem, caused by wide fluctuations in the concentration of organics in the waste streams being fed to the converter, was complete overhaul and repair of corroded bubble-cap trays in the distillation column which supplied waste A to the process. Since these modifications to the distillation column did not provide the degree of uniformity of feed desired, provision was made for the addition of dilution steam to the process so that wider variations of feed composition might be handled. This dilution steam added only an inert material which leveled the temperature effect of the fluctuations in organic material being fed to the converter. It normally would be more economical to provide sufficient capacity in the air blower to permit the use of excess air instead of steam as the diluent material. Steam was used in this case because of air-blower design limitations.

After initial lightoff and relatively uniform performance were secured, the unit operated for several days before the advent of the next problem—excessive temperature in the heat exchanger. Overdesign of the heat exchanger made

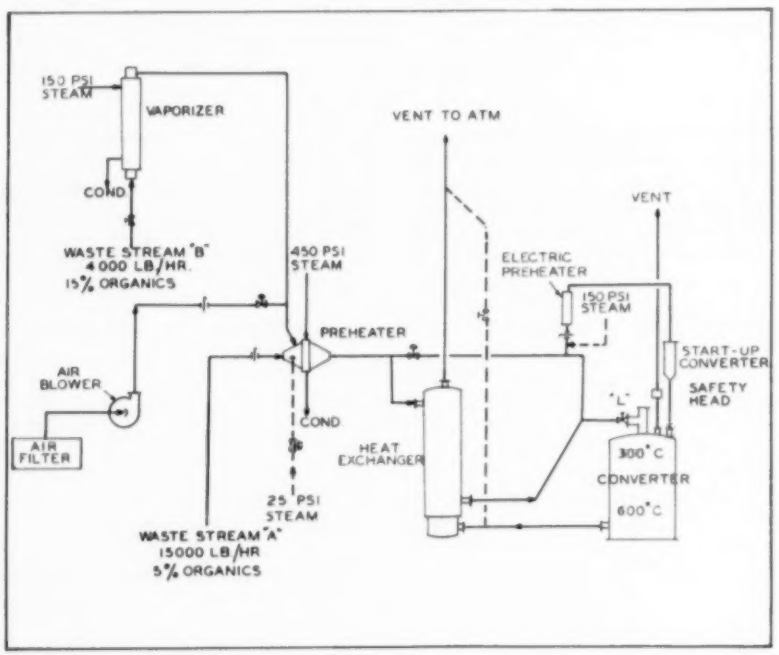

Fig. 2.

it necessary to reduce the quantity of cold gas passing through the exchanger to the point where it ignited within the exchanger itself without benefit of the catalyst. Excessive temperature at this point resulted in exposure of the exchanger exit piping and the top of the converter to a temperature above their design rating. The solution to this problem was to install a hot gas by-pass around the exchanger. The original development work had indicated that such a by-pass should be installed in preference to a cold-gas by-pass, but because of the difficulties anticipated from trying to operate an automatic valve at the temperature of the gas leaving the converter (600° C.), it had been decided to risk obtaining adequate control with the cold-gas by-pass. The hot-gas by-pass installed is manually operated and provides rough temperature control, and this with the existing automatic cold-gas by-pass and dilution steam addition provides satisfactory temperature control. It might seem that the catalyst is unnecessary for these operating conditions, but after careful analysis it appeared that ignition of the gases in the heat exchanger was caused by an unusually high concentration of organics in the waste streams; the catalyst is required to obtain ignition and good cleanup of the organic material at normal concentration.

The final major, and continuing, problem encountered was that of air-blower capacity. In order to conserve on investment, an air blower which met the desired capacity and head characteristics but provided little excess capacity was purchased. Accordingly, if the quantity of organics to be handled only slightly exceeded the design quantity expected, there was difficulty in obtaining the desired ratio of air to organics and hence the desired degree of oxidation. In addition, the necessity for adding dilution steam in the process, as mentioned earlier, further increased system pressure drop, thus reducing the slight excess capacity originally provided in the blower. The only solution to this problem is the expensive replacement of the blower with a larger unit or major revisions to the process equipment or piping to reduce pressure drop. The catalyst-bed thickness has already been reduced to the minimum consistent with good cleanup.

A few other problems encountered in the initial operation of this specific unit are not basic to catalytic-combustion processes. One was obtaining a packing material for the floating head of the heat exchanger which would withstand the temperature encountered. A satisfactory packing has not yet been developed, and it is necessary to replace the packing each time the unit is cooled. A water-cooled packing box would undoubtedly be the simplest answer on a new design. The second problem, the selection of the proper location of the temperature element controlling the automatic by-pass for good inlet-temperature control of the gases to the converter, was solved by only minor relocation of the thermocouple well. The third was a corrosion problem encountered as a result of incompletely vaporized waste material going to the unit from a distillation column. In the superheated state the vapor is noncorrosive, but small quantities of liquid carried over resulted in corrosion of the interconnecting mild steel piping. Stainless steel piping has been installed on a replacement basis as failure occurred. Finally, it was found necessary to install a layer of ceramic rings on top of the catalyst to prevent deterioration of the catalyst as a result of liquid waste impingement. This solution is satisfactory and has little effect on system pressure drop.

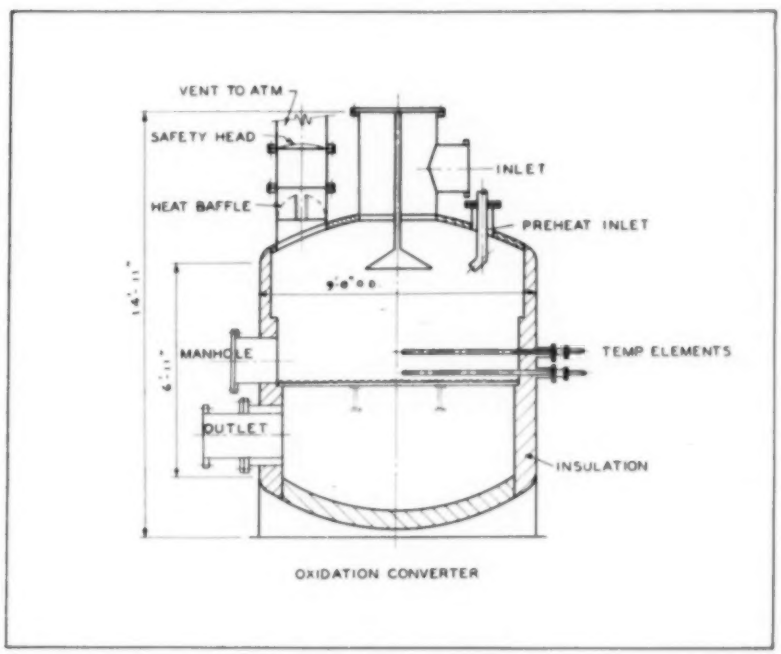

Fig. 3.

Conclusion

In summary, the process as developed and installed for the catalytic destruction of dilute organic aqueous waste materials has been successful. Now in essentially continuous operation, it destroys 97% of the organic material in these waste streams. A reevaluation of the process indicates that this method of disposing of dilute wastes is economical for the conditions encountered in this specific process. Additional units are being considered for similar waste disposal problems.

As in any other chemical process, careful attention should be given to the following factors in the design of a commercial installation: (1) adequate control of the ingredient flows should be designed into the system; (2) inlet-temperature and temperature-rise control must be provided; (3) provisions for handling upset conditions should be designed into the process; (4) provision of adequate materials of construction to handle the pressures, temperatures, and corrosive conditions to be encountered is essential.

Acknowledgment

The combined effort of several persons in the Belle Works technical and operating section, in particular C. P. MacDermott and Robert Thomson, who followed the start-up experience and carried out the changes necessary to obtain satisfactory operation, is responsible for the success of this process.

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Presented at Annual Meeting of the A.I.Ch.E. St. Louis, Mo.

CAST HEAT ALLOY REFERENCE SHEET

N. S. MOTT, Chief Chemist and Metallurgist

The Cooper Alloy Foundry Co., Hillside, N. J.

Alloy: Heat Resistant 28% Chromium Alloy.

Designations: A.C.I. HC; A.S.T.M. A297-49T Grade HC; S.A.E. 70446.

Chemical Analysis: C < 0.50%; Cr. 26-30%; Ni < 4%; Si < 2%.

Applications: Generally used for coarse furnace parts or where high sulfur conditions exist. Used for salt pots; sintering bars; grate bars and tuyeres; rabble arms and blades; dampers.

Machinability: This alloy is readily machinable, because of the combination of low ductility and toughness with high hardness.

Heat Treatment: Used in "as-cast" condition.

Weldability: Because of the low ductility and impact resistance of the alloy, welding is fairly difficult without cracking. Use a preheat of 250° F. and a postheat of 1650° F. for 2 hr. followed by air cooling. A rod of similar composition must be used.

TYPICAL MECHANICAL AND PHYSICAL PROPERTIES

	Room Temperature		1400° F.	1600° F.	1800° F.
	As Cast	Aged *			
Tensile Strength, 1,000 lb./sq.in.	83	85	10.5	5.1	2.5
Yield Point, 1,000 lb./sq.in.	48	53	8.7	3.8	2.1
Elongation, %	2	1	65	94	110
Reduction in Area, %	2	1			
Brinell Hardness	210	215			

* 24 hr. @ 1400° F. furnace cooled.

Charpy Impact (Std. Keyhole ft.-lb.)	1			
Mod. of Elasticity (X10⁶ lb./sq.in.)	29			
Density (lb./cu.in.)	0.274			
Melting Point (° F.)	2725			
Specific Heat (B.t.u./(lb.)(° F.)) @ 70° F.	0.12			
Thermal Expansion (x 10⁶ in. (in.) (° F.)) ° F.	70-1000	6.3		
	70-1500	6.8		
	70-2000	7.7		
Thermal Conductivity (B.t.u./(hr.) (sq.ft.)(° F/ft.)) ° F.	70-212	12.6	70-1500	20.3
	70-1000	17.9	70-2000	24.2
Electrical Resistance (microhms/cu.cm.) @ 70° F.	77			

HIGH TEMPERATURE STRENGTH: (lb./sq.in.)	1400° F.	1600° F.	1800° F.
Stress Rupture (100 hr.)	3,300	1,700	820
Stress Rupture (1000 hr.)	2,300	1,250	620
Creep (1% 10,000 hr.)	1,300	740	360

MAX. (° F.) TEMPERATURE FOR CORROSION RESISTANCE:

Air Oxidation Resistance	2000
Oxidizing Sulfur Bearing Flue Gas (Low Sulfur)	2000
Oxidizing Sulfur Bearing Flue Gas (High Sulfur)	2000
Reducing Sulfur Bearing Flue Gas (Low Sulfur)	2050
Reducing Sulfur Bearing Flue Gas (High Sulfur)	2000

High Temperature Corrosion Resistance:

Molten Neutral Salts . . . . . Poor

Molten Metal Resistance . . . . Good resistance to molten magnesium. Not resistant to molten aluminum.

Carburization Resistance:

Pack Carburizing . . . . . Poor

Gas Carburizing (< 15% CH_4). Excellent

Carburizing in Natural Gas (High CH_4) . . . . . Good

General High Temperature Characteristics:

This alloy has poor resistance to thermal fatigue cracking; also to the detrimental effect on mechanical properties of cyclic heating. Its hot ductility and impact properties are excellent, but its high temperature strength and hardness values are low. It has the best resistance of all the high temperature alloys to hot sulfur gases and molten fuel ash.

No. 36

the ROCKY MOUNTAIN SECTION
cordially invites you to

Come West... and Go Western!

R. M. Berry | Julius Hyman & Company, Shell Chemical Corporation, Denver, Colorado

Colorado is a good place to visit any time of the year, but in September, it displays the brilliant beauty of yellow aspen against a background of verdant evergreen. The fish—always numerous—are high spirited at this time, and obligingly the State fish and game regulations make it possible to enjoy a good catch.

Glenwood Springs, the site of the A.I.Ch.E. meeting, was chosen for several reasons. In the heart of the Rockies at 5,758 feet above sea level, it offers the vacationer almost every facility to be desired. In the heart of the great Colorado mining and mineral processing region it makes possible a combination of appropriate technical symposia and trips to installations of outstanding chemical engineering interest.

September means warm days and cool nights in the Rockies. A bit of rain is not unusual; nor is an occasional snow flurry in the highest reaches of the mountains. So come prepared—but come informally with blue jeans and checkered shirts. To maintain an atmosphere of traditional western informality, jeans and checkered shirts will be the preferred attire. Those arriving without them may make appropriate purchases through the Hotel.

Hotel Colorado, the meeting headquarters, offers a wide variety of facilities to please everyone. The rates of $12 a day American Plan cover all hotel facilities including the open air swimming pool and a pasture with nine gopher holes where you can chase your golf ball. The Hotel will extend this rate to conventioneers arriving before or leaving after the meeting.

How to Get There

Glenwood Springs is located 168 miles west of Denver and 90 miles east of Grand Junction, Colo., on U. S. Highway 6. It is also on the main line of the Denver and Rio Grande Western Railroad. The California Zephyr of the D.&R.G.W. reaches Glenwood Springs at 2:00 P.M. from the East or 1:35 P.M. from the West. Those preferring the scenic route via the Royal Gorge may take the 9:00 A.M. train from Denver, reaching Glenwood at 8:27 P.M.

Those who fly may land at Grand Junction, Colorado (90 miles distant), where rail or commercial bus transportation to Glenwood Springs is available. United Air Lines has two flights each

▲ Approach to Glenwood Canyon.

Snowmass Lake and Hagerman's Peak—"fisherman's and photographer's paradise." ▼

Hotel Colorado.

day to Grand Junction: No. 603 from the East and 648 from the West. Frontier Air Lines operates between Denver and Grand Junction, connecting at the former with United, Continental, Western, and Braniff. Continental Trailways bus line has three scheduled services each day from Denver and from Salt Lake City.

On the Social Side

For early arrivals, members of the Rocky Mountain Section extend an invitation to a scenic drive in private cars through the Glenwood Springs area, including Lookout Mountain Park, the State Fish Hatchery, and beautiful Glenwood Canyon. Cars will begin leaving about 1:00 P.M. for a trip of about two hours. Other goings-on will include swimming, golf, horseback riding, and a dramatically breathtaking ride on a chairlift which provides a view of the surrounding countryside.

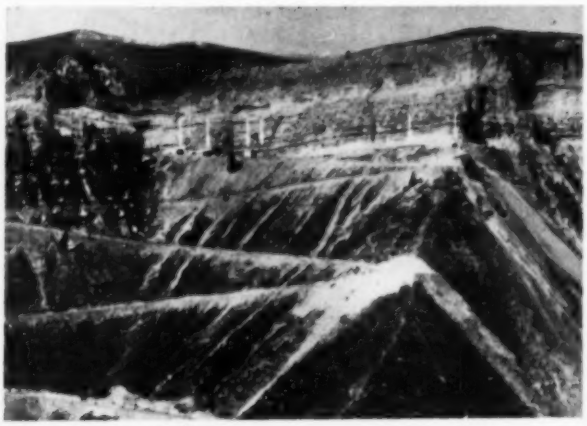
The meeting kickoff will be at the traditional Institute cocktail party, which will be held at the Hotel Colorado on Sunday night. For the energetic, a before-breakfast horseback ride will be offered each morning. A trip is planned each morning to Aspen, Colorado's famous winter ski resort. This will include a ride to the top of Ajax Mountain on the Aspen three-mile chairlift, which provides an unparalleled view of the Elk Range. Also, each morning a trip will be offered up the Crystal River to the ghost town of Marble, Colorado. From nearby quarries, stone was taken for the Tomb of the Unknown Soldier and the Lincoln Memorial. The town and its narrow-gauge railroad were abandoned in the mid-thirties. Along the river is some of Colorado's most spectacular scenery.

Monday evening will highlight the social program with an authentic chuck wagon dinner on the hotel patio fol-

plant & mine TRIPS

Air view of Bureau of Mines Oil Shale Engineering Experimental Station near Rifle.

(Courtesy—Bureau of Mines)



As indicated by arrows, these Bureau of Mines experimental oil shale mining facilities near Rifle, are, left to right, the two portals of the underground quarry, the office and warehouse, charge house, shop and compressor building, and the haulage portal of the selective mine. Note switchbacks on road.

(Courtesy—Bureau of Mines)

Climax's molybdenum mine at Climax, Colorado; the largest underground mine in North America, producing 27,000 tons a day.

(Courtesy—Climax Molybdenum Co.)

The MEN behind the MEETING

Seated—Robert Hawley, plant trip; Leo Roth, publicity; George Lof, Paul Manning, co-chairmen; Holger Figge, registration; Standing—Warren French, entertainment; Hugh Harris, hotel arrangements; Walter Wilson, printing; Richard Berry, publicity.

TECHNICAL PROGRAM

Glenwood Springs Meeting

Monday, September 13, A.M.

TECHNICAL SESSION No. 1

SYMPOSIUM ON OIL SHALE AND SHALE-OIL PROCESSING, W. I. R. Murphy, Presiding.

ADVANCEMENTS IN FUEL PRODUCTION FROM OIL SHALE, Clyde Berg, Union Oil Company of California, Los Angeles, Calif.

THERMAL EXTRACTION OF OIL-SHALE KEROGEN, W. R. Thompson and C. H. Prien, Denver Research Institute, University of Denver, Denver, Colo.

THERMAL PROCESSING AND CHEMICAL TREATING OF COLORADO SHALE OIL, Boyd Morris and Russell J. Cameron, U. S. Bureau of Mines, Rifle, Colo.

CATALYTIC CRACKING OF SHALE-OIL COKE DISTILLATES, C. K. Viland, Tide Water Associated Oil Co., Associated, Calif.

RECYCLE HYDROGENATION OF SHALE-OIL CRUDES, R. L. Crecelius, E. O. Kindschy, C. B. Hopkins, H. C. Carpenter, C. M. Frost, E. R. White, G. C. Freeman, and P. L. Cottingham, U. S. Bureau of Mines, Laramie, Wyo.

Monday, September 13, P.M.

TECHNICAL SESSION No. 2

(Simultaneous with Session No. 3)

SYMPOSIUM ON URANIUM ORE PROCESSING AND REFINING, R. H. Long, Presiding.

METHODS OF URANIUM EXTRACTION FROM VARIOUS ORES, Wm. L. Lennemann, Processing Division, Grand Junction operations office, U. S. Atomic Energy Commission, Grand Junction, Colo.

VANADIUM ASPECTS OF URANIUM MILLING OF CARNOTITE ORES, Fred A. Brinker, Western Division, Vanadium Corp. of America, Durango, Colo.

ROASTING AND LEACHING NON-CARNOTITE ORES, J. D. Moore and Edward Bernsohn, Vitro Uranium Co., Division of Vitro Corporation of America, Salt Lake City, Utah.

AN EXPLANATION OF THE FLOWSHEET AND PROCESSING CONTROLS OF THE MONTICELLO, UTAH, URANIUM MILL, R. L. Philippone, Processing Division, Grand Junction operations office, U. S. Atomic Energy Commission, Grand Junction, Colo.

ANALYSIS OF URANIUM MINERALS BY X-RAY SPECTROGRAPHY, M. L. Salmon and J. P. Blackledge, Denver Research Institute, University of Denver, Colo.

TECHNICAL SESSION No. 3

(Simultaneous with Session No. 2)

GENERAL TECHNICAL PROGRAM, J. E. Stepanek, Presiding

TECHNIQUE FOR CONTACTING GASES WITH COARSE SOLID PARTICLES, K. B. Mathur and P. E. Gishler, National Research Council, Ottawa, Canada.

PROBLEMS AND METHODS IN SPRAY ANALYSIS, W. W. Hagerty and R. A. Yagle, University of Michigan, Ann Arbor, Mich.

TURBULENCE IN FALLING LIQUID FILMS, C. Stirba and D. M. Hurt, Engineering Dept., Dupont Co., Wilmington, Del.

THE FALL OF SINGLE LIQUID DROPS THROUGH WATER, Shengen Hu and R. C. Kintner, Illinois Institute of Technology, Chicago, Ill.

PREDICTION OF VAPOR-LIQUID EQUILIBRIUM RELATIONS BY THERMODYNAMIC EXAMINATION OF ACTIVITY COEFFICIENTS, Albert H. Wehe and Jesse Coates, Dept. of Chem. Eng., Louisiana State University, Baton Rouge, La.

Tuesday, September 14, A.M.

TECHNICAL SESSION No. 4 *

SYMPOSIUM ON AGGLOMERATION, A. P. Weber, Presiding

AGGLOMERATION IN THE CHEMICAL PROCESS INDUSTRIES, Cecil H. Chilton, *Chemical Engineering,* New York.

GRANULATION OF MIXED FERTILIZERS BY AGGLOMERATION, John O. Hardesty, Fertilizer and Agricultural Lime Section, Soil and Water Conservation Research Branch, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Md.

BALLING AND PELLETIZING OF IRON ORE CONCENTRATES, Strathmore R. B. Cooke, School of Mines and Metallurgy, University of Minnesota, Minneapolis, Minn., and Thomas E. Ban, Cleveland-Cliffs Iron Co., Ishpenning, Mich.

* No technical sessions in the afternoon. Open for plant trips, sightseeing trips and recreation.

SNOWBALL PELLETIZING, H. E. Rowen, Dwight-Lloyd, Inc., Division of Sintering Machinery Corp., Netcong, N. J.

SONIC AGGLOMERATION AND COLLECTION OF CARBON BLACK AEROSOLS—PILOT PLANT AND COMMERCIAL TESTS, C. A. Stokes, Godfrey L. Cabot, Inc., Boston, Mass.; R. S. Boyd, Cabot Carbon Co., Pampa, Tex.; E. J. Holland, Georgia Pigment, Inc., Division of Cabot Carbon Co., Sandersville, Ga.; and J. E. Vivian, Massachusetts Institute of Technology, Cambridge, Mass.

COAL BRIQUETTING IN FRANCE, J. Charbonnier and J. Lusinchi, Centre d'Etudes et de Recherches des Charbonnages de France, Laboratoire de Verneuil (Oise), France.

Wednesday, September 15, A.M.

TECHNICAL SESSION No. 5 *

SYMPOSIUM ON ROLE OF CHEMICAL TECHNOLOGY IN RESOURCES FOR THE FUTURE, R. H. Ewell, Presiding

RÉSUMÉ OF THE FUTURE RESOURCES PROBLEM, Raymond H. Ewell, National Science Foundation, Washington, D. C.

ROLE OF AGRICULTURAL CHEMICALS IN COMPENSATING FOR OUR DIMINISHING FARM LAND, Paul D. V. Manning, International Minerals and Chemical Corp., Chicago, Ill.

ROLE OF SYNTHETIC PLASTICS IN FUTURE SHORTAGES OF METALS, WOOD AND OTHER MATERIALS, Charles E. Staff, Bakelite Co., New York, N. Y.

ROLE OF CHEMICAL TECHNOLOGY IN DEVELOPING NEW SOURCES OF ENERGY, Merritt L. Kastens, Stanford Research Institute, Stanford, Calif.

ROLE OF THE LIGHT METALS IN RELIEVING FUTURE SHORTAGES OF HEAVY METALS, A. C. Byrns, Kaiser Aluminum and Chemical Corp., Oakland, Calif.

ROLE OF IMPROVED EXTRACTIVE METALLURGY IN INCREASING USABLE RESERVES OF MINERALS, Oliver C. Ralston, Bureau of Mines, Washington, D. C.

* No technical sessions in the afternoon. Open for plant trips, sightseeing trips, and recreation.

Thursday, September 16 †

† No technical sessions. Open for plant trips, sightseeing trips and recreation.

Mighty nice mess o' fish for these parts.

Maroon Bells and Maroon Lake.

lowed by a square dance. Local dance groups will lead the way and offer friendly counsel to beginners.

Open House at Outstanding Mineral Processing Facilities

An outstanding feature of the technical program is the coupling of symposia with trips to outstanding plant sites.

Monday morning's symposium on Oil Shale and Shale Oil Processing is

(*Continued on page 73*)

(continued from July)

ANN ARBOR — Part 2

The first national meeting sponsored by the Nuclear Engineering Division of the Institute—First International Nuclear Engineering Congress—was a remarkable success. Uniting a restful university "campus in the summer" atmosphere with a distinctly international flavor, the Congress gave chemical engineers from industry their first major opportunity to receive "advanced training" which would acquaint them with nuclear developments as they are now available for industrial application.

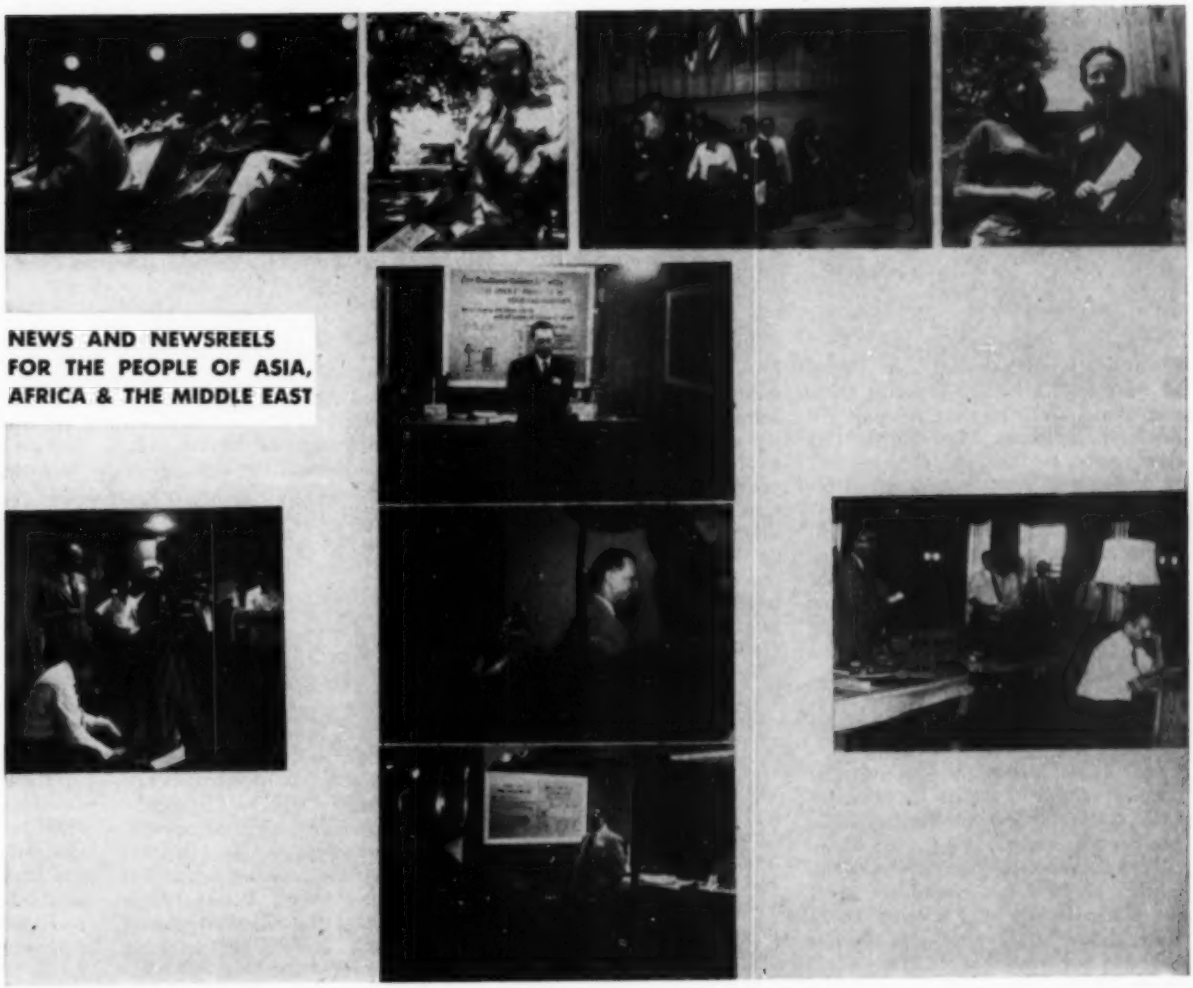
Training in nuclear engineering in the universities is being given at present on a basis of amending basic training in the traditional professions and technologies, rather than as a separate curriculum, reported a panel of educational leaders headed by Manson Benedict (M.I.T.). The desirability of such was voiced by industrial speakers (see picture at top of page).

OTHER COUNTRIES (*Continued from July*)

Oliver Townsend's remarks on nuclear development the world over included France ("has some uranium, and a plant for processing ores . . . embarked on 5-yr. plan, largely to produce plutonium, a fissionable fuel"); Canada ("has some of world's richest uranium deposits . . . is building reactors which will manufacture plutonium . . . hopes to have a power plant operating by 1962"); Sweden ("does have deposits of uranium, occurring in shales. Is building reactors, and is interested in producing power because of lack of coal or oil"); Switzerland ("has plans for a reactor, but possesses virtually no uranium"); Germany ("will probably build a research reactor as soon as Allies permit"); Portugal ("has uranium but no immediate reactor plans"); Australia ("substantial uranium deposits and intensive development program including at least one reactor"); Brazil ("may have uranium and would like to build a reactor soon"); and Japan ("which has the highest power costs of any of the world's industrialized nations, plus scientific talent, but which has no uranium to speak of, and—at present—no plans to build a reactor"). Japan, incidentally, sent a representative.

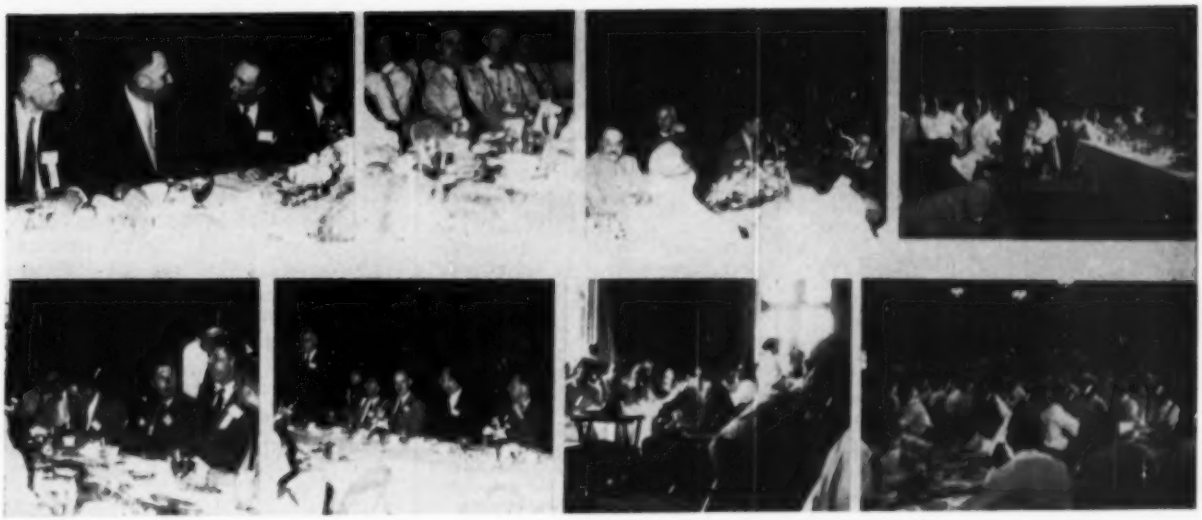
PICTURE FEATURES

Shown on the following pages are groups of pictures taken by the C.E.P. staff. It is hoped that these photographs will give an interesting impression of a great A.I.Ch.E. meeting.



NEWS AND NEWSREELS FOR THE PEOPLE OF ASIA, AFRICA & THE MIDDLE EAST

LUNCHEONS & BANQUETS



(More pictures on page 42)

nuclear engineering division

INSTITUTE'S FIRST DIVISION MAKES GOOD START

Scarcely seven months have passed since the Nuclear Engineering Division of A.I.Ch.E. was organized in St. Louis on December 14, 1953. In this short space of time the Division has gained over 800 members and has already served as sponsor of the largest technical meeting on nuclear energy held in this country, namely the International Congress on Nuclear Engineering that convened at Ann Arbor, Michigan, June 20-25, 1954.

The Division was started through the hard work of a number of people and through the cooperation and foresightedness of the Council of the Institute, for it was through these combined efforts that there was created the organizational framework within which the Division could exit. The first move in this direction came several years ago when Council established a Nuclear Energy Committee. In 1952 this committee, under the chairmanship of Professor D. L. Katz, decided the time was at hand to have a national meeting of the A.I.Ch.E. devoted entirely to the field of nuclear energy. Council gave its approval in November, 1952 for such a meeting to be held at Ann Arbor. Serious effort towards arranging the technical program began on February 28, 1953, with a meeting of the Nuclear Energy Committee of the Institute along with invited persons from the nuclear field. On January 19, 1953, Dean M. P. O'Brien of the University of California, at Dean L. M. K. Boelter's request, wrote to Dean G. G. Brown of the University of Michigan and suggested that the A.I.Ch.E. sponsor an organization that would bring together persons interested in the advancement of nuclear engineering. Dean O'Brien's letter was referred to the Nuclear Energy Committee and the possibility of such a group was discussed at the meeting held on February 28, 1953. A letter to Council on March 3, 1953, apprised Council of Dean O'Brien's letter and of the discussion by the Nuclear Energy Committee.

George Holbrook, as Chairman of the Committee on the Future of the Institute, considered the matter and recommended to Council that a Division be formed to serve the Nuclear Engineering area (April 21, 1953). Council indicated informally that by-laws be developed for a division and this was done in cooperation with the Committee assembled on October 31, 1953, to work on the program for the Congress. The proposed Constitution was distributed in late November and a meeting was called for December 14, 1953 at St. Louis to organize the Division. The Constitution with minor modifications was adopted at St. Louis by a group of about 60 people attending. Officers and an Executive Committee were elected.

The Executive Committee has had two meetings, one on March 6, 1954, and the other during the Congress. Committees on Membership (R. N. Lyon, chairman); Program (L. M. K. Boelter, chairman); Publication (Manson Benedict, chairman); and Nomination (Miles Leverett, chairman) have been appointed. There were 773 members of the Division as of July, 1954, of whom over half are not members of A.I.Ch.E.

Although the Division has got off to a good beginning with the International Congress, it has many problems to solve. First there is the question of meetings. At the present time it is proposed to have at least one annual meeting devoted to nuclear engineering such as the Congress, and possibly other meetings held as symposia with regular meetings of the A.I.Ch.E. In that connection the Division at its business meeting during the Congress decided to join with the University of California in the sponsorship of a Conference on Nuclear Engineering on the U.C.L.A. campus, April 27-29, 1955. No other meetings have been formally planned as yet.

A second problem is concerned with publications. As a starter the Division's papers presented at Ann Arbor have been published in C.E.P. and the Symposium Series. The May issue of C.E.P. was devoted exclusively to these papers and the first of the three Symposium Series volumes was published prior to the Congress. The second will be available shortly, and the third in a few weeks. Whether these means will meet the ultimate publication needs of the Division is a point that needs further discussion.

A third problem involves the methods by which the Division can serve an interested group on a local basis. According to the by-laws, the Division is to serve as a meeting place for nuclear engineers to discuss problems of material interest, to present papers in the field, and to initiate the publication of such papers. In endeavoring to set up conditions under which groups can meet together locally, the Division took the position that it would take steps to organize local sections just as soon as any group came to the Division and demonstrated that there is sufficient interest in a given area to support a continuing effort on a local basis.

All readers who would like to join the Division are invited to send an inquiry to J. J. Martin, Secretary-Treasurer, Nuclear Engineering Division, 2028 East Engineering Building, University of Michigan, Ann Arbor, Michigan.

Donald L. Katz
J. J. Martin

Ann Arbor, July, 1954.

THE MEN WHO PLAYED A MAJOR PART IN ORGANIZING THE DIVISION

The following persons were members of the Committee on Nuclear Engineering who, as explained in the accompanying article, organized the Congress, and played a prime part in organizing the Division:

Donald L. Katz	H. J. Gomberg
J. J. Martin	H. S. Isbin
R. H. Beaton	J. A. Lane
J. E. Beckerley	Stephen Lawroski
Manson Benedict	M. C. Leverett
G. G. Brown	Stuart McLain
L. E. Brownell	A. F. Thompson
J. W. Clegg	F. J. Van Antwerpen
T. B. Drew	Harvey Wagner
R. C. Ernst	L. C. Widdoes

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CANADIAN, U. S. FIRMS TO PRODUCE LITHIUM

Lithium, the metal recently given prominence in connection with thermonuclear weapons, is expected to be in sufficient supply in the United States soon as a result of an agreement whereby Lithium Corp. of America, Inc., will process the entire output of a concentrating mill to be erected by Quebec Lithium Corp. at an important ore body near Val d'Or, Quebec, owned by the Canadian firm.

Lithium Corp. of America, which will double the output of its plants with the addition of the Canadian ore concentrates, will process them at its chemical plants at St. Louis Park, Minn., and Bessemer City, N. C.

CENTURY-OLD CRANE CO. TO PRODUCE TITANIUM

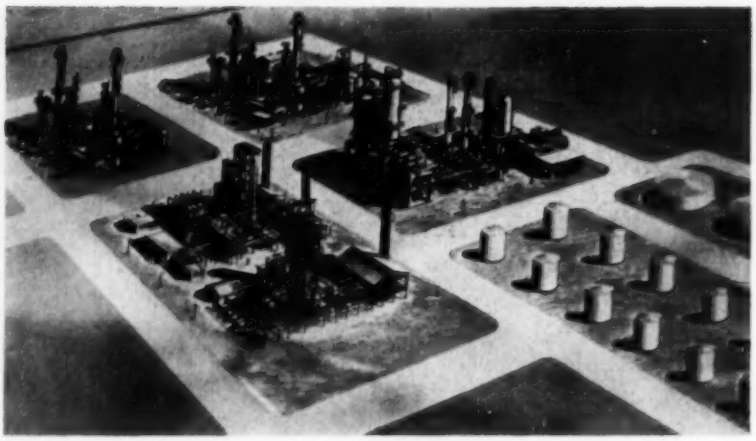
The largest manufacturer of valves in the world will observe its one hundredth birthday by entering into rare-metals production when the Crane Co., founded on July 4, 1855, opens its titanium plant at Chattanooga, Tenn., sometime in 1955.

The $25 million titanium-ore processing plant will initially direct most of its output toward the Air Force, but when supplies permit, the company anticipates the use of titanium in valves and fittings manufactured for use under highly corrosive conditions in the chemical, petroleum, aircraft, and marine industries.

The company through its subsidiary Cramet, Inc., has a contract with the Defense Materials Procurement Agency that calls for the Federal government to advance $24,950,000 to Cramet for construction and equipment costs to be repaid with interest as titanium sponge is produced. Cramet is to produce 30,000 tons of titanium sponge during a 5-year term, with the government having an option to buy up to 7,500 tons during the period at the rate of $5/lb. during the first year and at $4 or market price, whichever is greater, thereafter for the duration of the contract. The Government is not required to take more than 1,000 tons at the $5 rate.

Crane Co. holds several mining claims in Quebec and will dredge titanium ore from 50,000 acres of Florida beach sand along the Gulf of Mexico. Other rare heavy minerals that will be recovered in the processing of titanium include zircon, cerium, thorium, and various fluorides and oxides. A newly formed subsidiary, Heavy Minerals, Inc., will process the ore.

NEW PUERTO RICAN REFINERY



Artist's conception of the petroleum refinery being constructed at Guayanilla Bay, Puerto Rico, for Commonwealth Oil Refining Co., Inc. To be the largest of its kind in Puerto Rico, the refinery, which is being built by the Lummus Co., will process about 25,000 bbl./day of Venezuelan crudes to produce aviation and motor gasolines, bottled gas, kerosene, Diesel oil, and fuel oil. The plant will consist of a two-stage distillation unit; a Houdry catalytic reformer; a Houdry catalytic cracker; and vapor-recovery, alkylation, and polymerization units, together with auxiliary equipment.

Titanium, the fourth most abundant structural metal (after aluminum, iron, and magnesium), is 70% heavier and six times stronger than aluminum, about 40% lighter and nearly equal in tensile strength to steel. It is remarkably corrosion resistant, particularly to salt water. Ordinary processing methods cannot be used on titanium because it is extremely reactive; even exposure to air may spoil the metal. Much of the processing therefore must be done in a vacuum or in an atmosphere of inert gas, such as helium or argon, and the high melting point of titanium (3100° F.) must be taken into account.

DRYING-TOWER CONTROLS ADOPTED BY LEVER BROS.

A system for retarding combustion in the case of fire or overheating in continuous spray-drying towers has been announced by Lever Brothers. The system automatically shuts down the drying operation and actuates a variety of fire-retarding devices, among which are a rate-of-rise detector, which responds when the tower temperature rises at an abnormal rate, and fixed-temperature detectors, which are located in the tower and in each of the dust-collector bins.

The detectors control a master release which causes the air heater to shut off, eliminating further heat input; the air inlet and exhaust fans to shut off and their corresponding dampers to close, eliminating the normal air stream in the tower; a special damper in exhaust stacks to open, venting collected heat to the atmosphere; and alarms to sound in the plant and at a central fire station.

Fine soap dust always present inside the tower required the selection of a hermetically sealed detector, which contains within a stainless-steel outer shell the contacts that release the master circuit. The detectors are self-resetting and explosion proof.

Other devices in the drying towers are a timing device on the air heater that purges the air of the heater and tower for a predetermined period before the igniter for the heater can be actuated; flame-failure controls that shut down the heater in case the heater flame is inadvertently extinguished; and safety controls that prevent the heater from starting or cause it to cease operation in case of interruption of the air flow through the tower.

INCREASE IN MEXICAN OIL PRODUCTION

Increased facilities for Mexico's nationalized oil trust, Pemex, due in large part to equipment produced in the United States, have resulted in an expected output for 1954 of 85,000,000 bbl., almost 40% more than was produced in 1953, according to an announcement by the Worthington Corp., which supplied much of the machinery used in Mexico's new $25,000,000 refinery.

Since nationalization about fifteen years ago thirty-six new fields have been opened, and this year Pemex has completed one and a half new wells a day, increasing its drilling activities 33% over 1953. Pemex is also producing some lubricating oils and expects to be able soon to supply all of Mexico's lubricating-oil needs.

(*More News on page* 44)

10 years of research . . . over 75 years of pump manufacturing experience . . .

THE NEW PATENTED HILLS-McCANNAMETER "the meter that pumps . . ."

A. POSITIVE DISPLACEMENT METERING

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Check and compare with any other pump

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The Hills-McCannameter—"the meter that pumps"—establishes an entirely new set of standards for precision, accuracy and reliability in small volume metering and proportioning.

SPECIFICATIONS—Series "A"

Effective capacity range: 5 c.c. to 6 gal. per hr.
Standard pressure range: to 2500 psi (special designs to 10,000 psi).

If you have been looking for a pump that will *precisely* meter a wide output range of small volume flows, here is the answer. Write today. HILLS-McCANNA CO., 2438 W. Nelson St., Chicago 18, Illinois.

***See** the Hills-McCannameter in action at the Instrument Show, Sept. 14-24. Tickets for the demonstrations can be secured at Booth 101.*

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PRESIDENTS' RECEPTION

A.I.Ch.E. President C. G. Kirkbride and University of Michigan President H. Hatcher jointly greeted Congress guests at Hatcher's spacious home on the university grounds. The garden appeared more popular than the punch-bowl, except for the children present.

exposition

One of the most attended functions of the Congress was the "Atoms for Peace" exposition. Shown in the photos are some of the exhibits provided by industrial firms, universities, and government groups. The exposition served a useful purpose in demonstrating available plant equipment, laboratory devices and nuclear installation designs. Attendants at the booths were well qualified to answer the many questions put to them by guests.

Turning out a sweet job in tandem!

The high quality of the famous Hershey Chocolate Bar is known far and wide. And, into the maintenance of that product's well-deserved popularity, goes the processing of just the right kind of sugar.

In the Hershey Chocolate plant eight No. 4-TH-MIKRO-PULVERIZERS set up in tandem units, turn out tons of sugar per hour, reducing it to the required degree of fineness.

It was found that this dual-pass method reduced power consumption and operating time—while delivering at the same time a product which solved other problems in the subsequent processing of the chocolate.

A major part of all the sugar in the world is ground in MIKROS. So too, MIKROS have provided the answer to a great majority of food processing operations where grinding, blending or granulating of fine or ultra-fine powders is required.

The MIKRO area of distinguished service extends far beyond the food field. It also embraces the processing of chemicals, pharmaceuticals, cosmetics, soaps, fertilizers, plastics and many other products and materials.

Submitting your grinding or dust recovery problem to the MIKRO Laboratory involves no obligation on your part. But, the answer provided may be just the right answer for you.

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an old principle
—an extraordinary result

ball bearings rolling on a FLAT surface

- *offer less friction*
- *are easy turning*
- *wear longer*

EMSCO
BALL BEARING SWIVEL FITTINGS

It's an old principle, a ball rolling on a flat surface – making a single point of contact, and when applied to a ball bearing swivel fitting you get an extraordinary result – free and easy rotation even under extreme pressures. Compare EMSCO on this point!

Should you take the EMSCO fitting apart – and it's easy to do because it breaks like a union, you'll note a unique packing and ball race design which permits easy adjustment for wear. No expensive return of fittings to the factory for service. Note also how the large fluid passageways and smooth, easy contour of bends reduces turbulence and increases flow.

You'll find an EMSCO ball bearing swivel fitting for almost any application.

GET THE COMPLETE ENGINEERING STORY FROM OUR NEW CATALOG TODAY.

8 BASIC STYLES — OVER 500 MODELS

EMSCO MANUFACTURING COMPANY
BOX 2098, TERMINAL ANNEX
Houston, Texas • LOS ANGELES 54, CALIFORNIA • Garland, Texas
Representatives in principal cities

NEWS

(*Continued from page* 40)

INDUSTRY MAY RENT ANALOGUE COMPUTER TIME

Chemical engineers whose calculation problems are too complex for their slide rules may take them to an analogue computation center near Princeton, N. J. Opened by Electronics Associates, Inc., of Long Branch, N. J., on July 14, the center is the first available to industry on a rental basis.

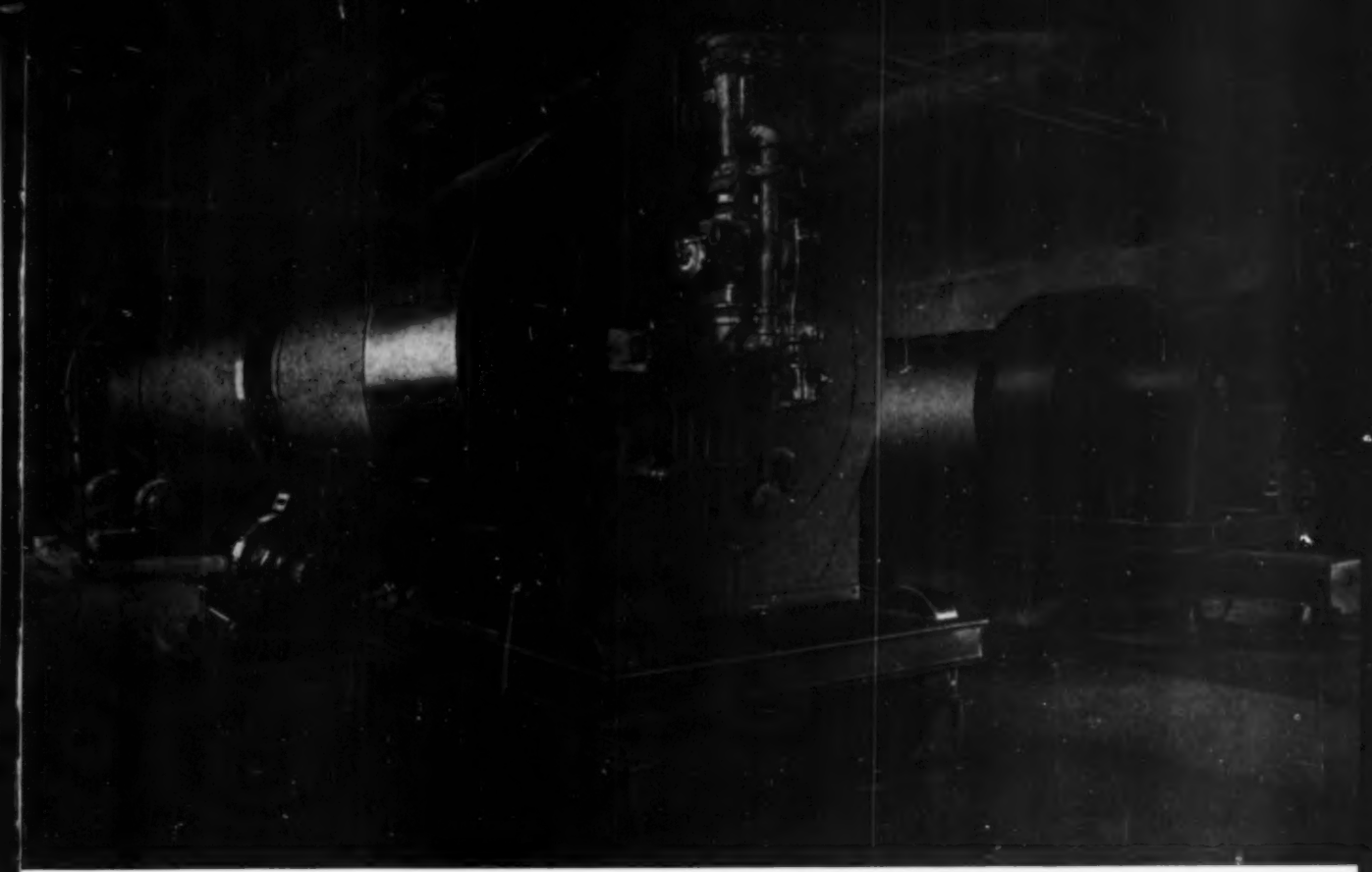
Equipment includes a dual-control console, operational amplifiers, servo multipliers, servo resolvers, servo-type function generators, a two-channel X-Y recorder, and a six-channel curvilinear recorder. Customers equipped to program their own problems are supplied with patch panels on which to prepare problems for the computer. The center will also supply scientists, engineers, and mathematicians to assist the customer or to undertake the entire computation.

A.I.CH.E. SYMPOSIUM AT I. S. A. CONGRESS

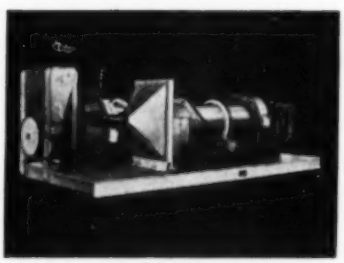
Materials - handling. instrumentation will be the theme of the A.I.Ch.E. symposium at the First International Instrument Congress and Exposition in Philadelphia on Sept. 23, 1954. Eleven papers will be presented: "Scope of the Materials Handling Instrumentation Field" by W. B. Heinz, Heinz Engineering Co.; "Level Measurements in Granular Solids" by F. S. Becker, Sun Oil Co.; "Applications of Ohmart Equipment to Measurement of Process Variables" by H. L. Cook, Jr., The Ohmart Corp.; "Application of SR-4 Strain Gauges to Materials Handling" by W. H. Bosworth, Ruge-deForest, Inc.; "Vane Type Flow Meters in Materials Handling" by George Fitzpatrick, Potter Aeronautical Co.; "Instrumentation for Specific Gravity Measurements and Weighing in Storage Tanks, Drum Filling, and Cranes" by C. E. Roessler, Automatic Temperature Control Co.; "Application of Gravimetric Feeders in Continuous Processing" by A. A. Melnychuk, Omega Machine Co.; "Electrical Auto-Batch Weight Control System for Solids" by B. L. Sutton, Gilmore Industries, Inc.; "Solving Low-Capacity Flow Control Problems" by W. P. Griffiths and J. Procopi, Milton Roy Pump Co.; "Applications of Instrumentation to Proportioning by Weight in the Process Industries" by W. M. Young, Richardson Scale Co.; and "Electronic Weighing in the Chemical Industry" by V. C. Kennedy, Jr., Streeter-Amet Co.

The congress, sponsored by the Instrument Society of America, will extend from Sept. 13 through 24.

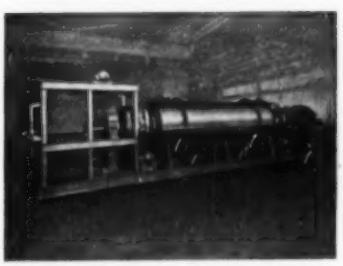
(*More News on page* 48)



direct fired Rotary Kilns



Special Stainless Steel Dryer for Processing a Costly Anti-Biotic without Contamination.



Calciner and Cooler for Continuous Processing at Temperatures from 900° F. to 2100° F.

Oil fired units can be rotated at speeds ranging from 2 Rev./Hr. to 5 Rev./Min. to control the length of time the material is under treatment.

Temperatures range from 1000° F. to 2200° F. depending upon the material being handled. Burners are controlled automatically with radiation pyrometers. Heated material is passed through a Bartlett-Snow externally water cooled cooler — and cooled slowly, at gradually declining temperatures. Use Bartlett-Snow's complete facilities — including materials handling — on your next job. It fixes unit responsibility — assures the smooth synchronized operation of the entire project — and utmost economy and satisfaction.

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FABRICATORS ERECTORS

Dryers • Coolers • Calciners • Kilns

"Builders of Equipment for People You Know"

There's more to instrumentation than instruments

Instruments can do wonders, if they're given the chance. But some one has to put them to work in the most effective way. And that's where Honeywell Application Engineering steps in.

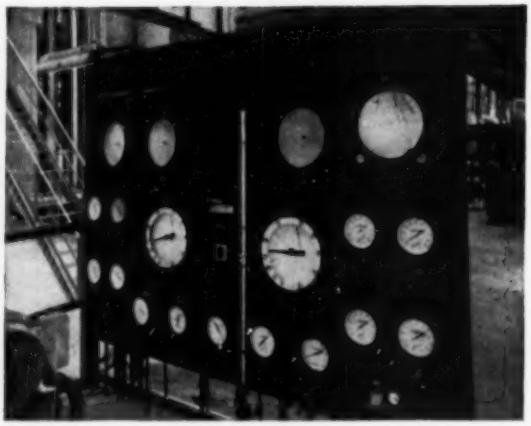
This service is one of the most important plus values you get in Honeywell instrumentation. It's a teamwork job. And every member of the team is an expert in his own field. Engineering begins right in your own plant, where a Honeywell field man digs out the vital facts about your process. He sits down with your engineers, production men and instrument technicians . . . and finds out everything he needs to know about what needs to be measured or controlled, to what accuracy, and under what conditions.

Then the problem goes to Honeywell's Application Engineering staff. Here's where you'll find groups of instrumentation specialists for every major industry. One group, for example, is devoted to the control problems of the metalworking industry. Another handles ceramic applications . . . another chemical . . . until together they cover the whole gamut of modern processes. These men know their specific field from years of first-hand experience. They're thoroughly familiar with the techniques of processing and the ways that instrumentation should be applied.

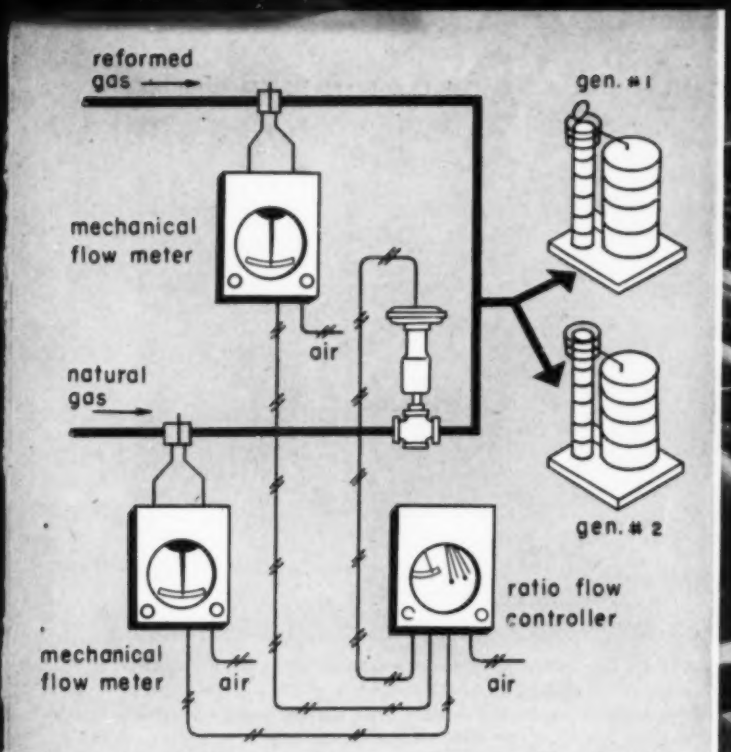
Honeywell Application Engineers develop detailed recommendations for the complete installation. They determine the most effective instruments, primary elements, types of control and valves for every phase of measurement and control. They add switches, signals, interlocks and other accessories which their experience indicates are needed in the interest of safety and convenience. Then they combine all components into a complete system—whether it involves a single instrument or a whole panel—that is designed for peak production efficiency, simple maintenance, and greatest convenience to operators.

This service saves time by doing engineering work that would tie up your own staff for many hours. And it pays off in assuring the excellent performance of which Honeywell instruments are capable.

Ratio controller regulates critical gas mixtures in



Control panel for carbon black generators includes (in upper right corner) Brown ratio flow controller . . . along with ***ElectroniK*** *instruments for checking temperatures inside the generators.*



Brown flow transmitters are mounted outdoors, next to natural gas and reformed gas lines. Diagram shows the complete ratio control system supplying a pair of carbon black generators.

carbon black production

Got a process in which two different gases must be supplied in exact proportion? Godfrey L. Cabot, Inc., were faced with a problem like this in their thermal carbon black plant near Franklin, Louisiana. And the Brown flow control system that was developed for this job in cooperation with The Gas Machinery Company may give you some ideas for your own applications.

The Cabot process cracks carbon out of natural gas, in cyclic reactors or generators designed and built by The Gas Machinery Co. To produce various grades of black, the natural gas fed to the generators must be diluted with reformed gas. A Brown two-pen ratio flow controller, working with two Brown mechanical flow meters, does the trick. The flow meters measure the flow in both the natural and reformed gas lines, and each transmits air pressure signals to actuate one of the ratio controller's pens. On the basis of these signals, the controller regulates a Honeywell diaphragm valve in the natural gas line, to maintain the required ratio of flows of natural gas and diluent.

This simple, rugged system provides excellent accuracy, to keep flow ratios at optimum values. It's versatile, too . . . can be readily set to allow feed of straight natural gas when coarse grades of carbon are required.

Many other types of flow instrumentation are available from Honeywell for the varied requirements of chemical processes. Your nearby Honeywell field engineer will be glad to discuss your specific applications . . . and he's as near as your phone.

Minneapolis-Honeywell Regulator Co., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

● **REFERENCE DATA: Write for new Catalog 2320, "Flow Meters, Indicating, Recording, Integrating and Controlling."**

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Honeywell
BROWN INSTRUMENTS
First in Controls

Now more than ever

PLANT ENGINEERS PREFER
Schmieg CENTRI MERGE
INDUSTRIAL EQUIPMENT for
✓ Long, Trouble-free Performance
✓ Low Maintenance Costs
✓ Ease of Installation
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All SCHMIEG equipment is designed, engineered, manufactured, and installed with the fundamental objective of protecting and improving the quality of the product you manufacture.

CONSULT SCHMIEG ENGINEERS and find out how a Schmieg installation will keep your plant operating at highest efficiency levels at lowest possible cost.

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NEW AMMONIA PLANT BEING BUILT AT TUSCOLA BY NATIONAL DISTILLERS

Foundations are being laid for the new ammonia plant being erected at Tuscola, Ill., for National Distillers Products Corp. by The M. W. Kellogg Co. The main feature of the plant is a special quench-type reactor that allows the temperature control necessary for a reaction that must be carried out at temperatures near those at which the catalyst deteriorates rapidly.

MATHIESON INSTALLS TELEGRAPH SYSTEM

A 5,000-mile, high-speed, private wire-telegraph network has been installed by Mathieson Chemical Corp. to speed intercommunication among its thirty-one plants and offices throughout the country. Encompassing fifteen states and twenty-three cities, the system has a capacity of 24,000 words an hour. Messages prepared in the form of perforated tape will be received in page form ready for instant use.

NEW DESIGNATIONS FOR WROUGHT ALUMINUM

A change in the alloy-designation system for wrought aluminum and aluminum alloys has been announced by The Aluminum Association to become effective on Oct. 1, 1954. Consisting of four-digit numbers, the new system is expected to meet all the present and foreseeable needs for wrought alloys. The first digit of each designation indicates the general group to which the alloy belongs; the second digit indicates any modifications of the original alloy or impurity limits; and the last two digits identify the alloy or indicate the aluminum purity. To aid in the transition to the new system, many of the old numbers are retained as the last two digits of the new numbers; thus alloy 24S becomes 2024. The first digit identifies the following major alloying elements: 1, aluminum 99.00% minimum and greater; 2, copper; 3, manganese; 4, silicon; 5, magnesium; 6, magnesium and silicon; 7, zinc; 8, other elements; 9, unused series for possible additional designations.

The new system is expected to be adopted throughout the industry, and copies of the pamphlet explaining it can be obtained from aluminum distributors.

REACTORS AVAILABLE FOR COMMERCIAL USE

Two atomic research reactors to be used in training personnel and in conducting basic nuclear research have been announced by Babcock & Wilcox Co. The designs are modified versions of the water-boiler and swimming-pool reactors developed by the Atomic Energy Commission laboratories and will sell in a range of $100,000 to $150,000.

When present restrictions are relieved to allow industry to participate in the development of nuclear power, C. H. Gay, vice-president, estimated, "future requirements for physicists and engineers will probably be at least 6000 [reactors] more in the next eight years." The swimming-pool type will probably be more expensive than the water-boiler reactor but will also offer additional advantages such as space for bulk shielding; the water boiler has been designed to obtain the highest possible neutron flux per investment dollar.

Governmental approval is required before any institution may construct one of these reactors either for research or for production of radioisotopes.

(*More News on page* 50)

Chlorine...

for Refrigerants

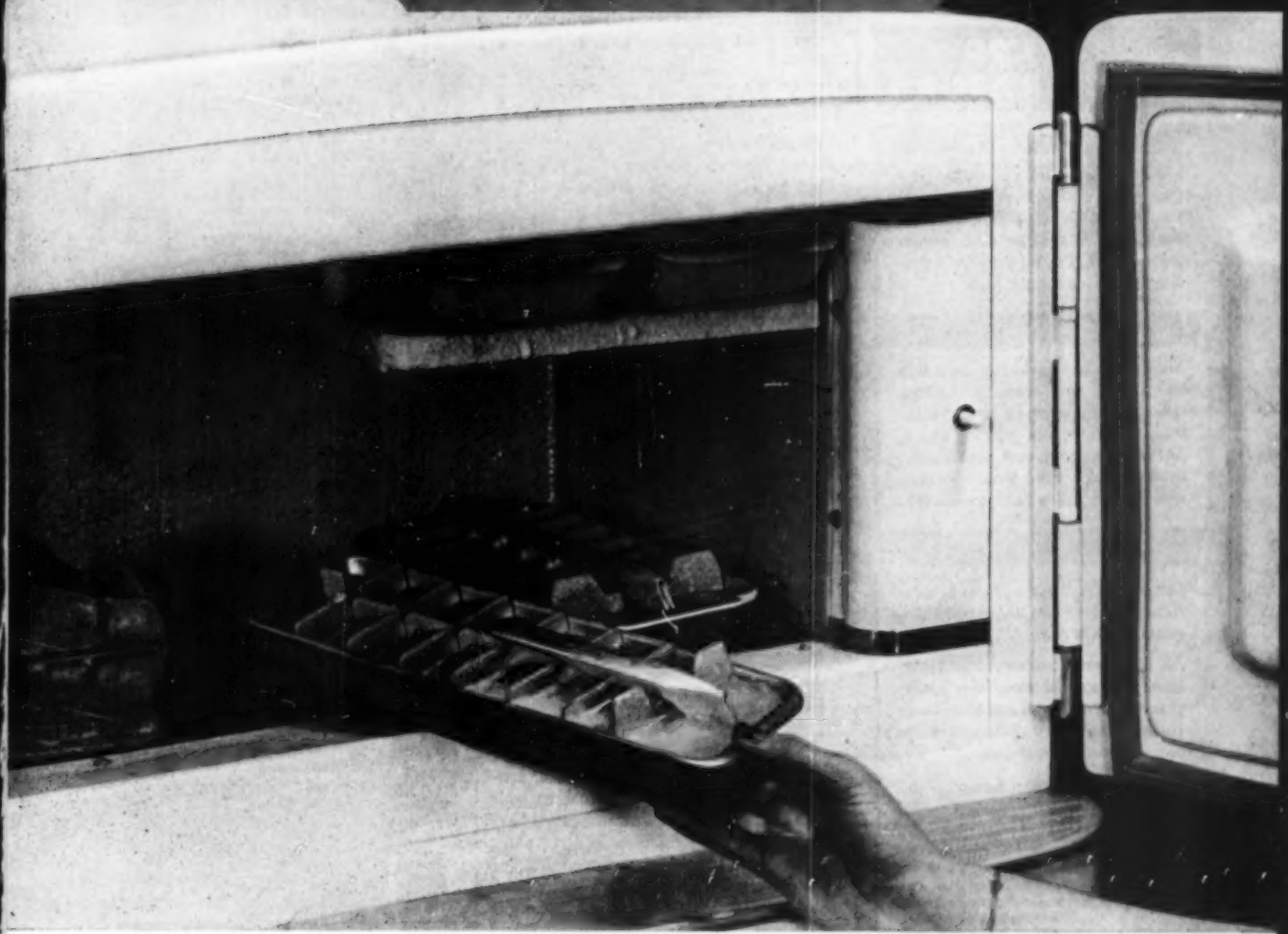
Ice making, air conditioning and countless other cooling operations depend upon the economy and efficiency of chlorine-made refrigerants.

Uniformly high quality GLC GRAPHITE ANODES play an equally important part in helping the electrolytic industry meet the growing civilian and defense needs for chlorine and caustic soda.

ELECTRODE DIVISION

Great Lakes Carbon Corporation

Niagara Falls, N.Y. GLC Morganton, N. C.



Graphite Anodes, Electrodes, Molds and Specialties

Sales office: Niagara Falls, N.Y. **Other offices:** New York, N.Y., Oak Park, Ill., Pittsburgh, Pa.

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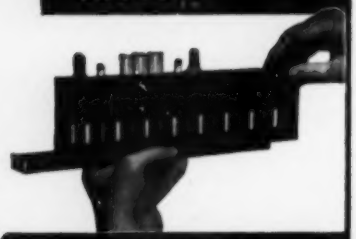
Want the easiest way to make fast, accurate

pH, CHLORINE TESTS?



TAYLOR COMPARATORS

EASIEST...

because three simple steps give you the determination; every Taylor set is supplied with all necessary reagents and accessories. And, Taylor sets are lightweight, yet strongly built.

FAST...

because many tests can be made in only a few seconds. Others take no longer than a few minutes. Taylor sets are compact, portable so you can make tests on-the-spot, no time wasted carrying samples back to the lab.

ACCURATE...

because all Taylor liquid color standards carry an unlimited guarantee against fading.

All standards for any one determination are housed in a single plastic slide. No single standards to handle. Many different slides can be used on one base.

See Your Dealer Soon!

FREE MANUAL

"Modern pH and Chlorine Control" illustrates and describes full Taylor line. Also gives useful data on theory and application of pH and Chlorine control. Write today.

W. A. TAYLOR AND CO.
412 RODGERS FORGE RD. • BALTIMORE 4, MD.

NEWS

(Continued from page 48)

DU PONT OFFERS NEW POLYESTER FILM

Mylar polyester film, made from a polymer formed by the condensation reaction between ethylene glycol and terephthalic acid, was recently introduced by Du Pont Co. Made currently in eight gauges and three types, the film, according to its manufacturer, has a tensile strength one third that of machine steel, is resistant to moisture and chemical attack, and has an operating temperature range from −60° to 150° C. and a high dielectric strength. A transparent film, the product can be printed, embossed, and laminated for use as a decorative, insulation, or lining material.

The new $10,000,000 plant to manufacture Mylar is being completed at Circleville, Ohio, and will replace the present pilot plant facilities in Buffalo.

NEW FATTY ALCOHOL PROCESS FROM BLAW-KNOX

Plants using the Belgian S.B.A. process for the production of fatty alcohol by continuous hydrogenation are available to U. S. industry according to an announcement by Blaw-Knox Co. The process, which is currently operating in Europe, consists of the following steps: (1) continuous methyl ester production (transesterification and fat splitting followed by esterification), (2) continuous hydrogenation of the carboxyl group, (3) continuous hydrogenation of the unsaturation existing in the raw material, (4) continuous fractional distillation of the crude alcohol.

Pilot-plant facilities are available for the testing of domestic raw feed materials. They are capable of continuous operation similar to that of full-scale plants and can process 1 bbl. of fat or fatty acid a day, results of which, such as yield and catalyst life, the company claims, can be projected accurately to commercial operation.

SHELL INTRODUCES NEW ACID PROCESS

The first full-scale commercial plant designed to prepare a monobasic aromatic acid by a one-step oxidation process is how Shell Chemical Corp. characterizes its new Martinez, Calif., plant constructed for the manufacture of paratertiary butylbenzoic acid. The acid, according to Shell Development Co., is made by blowing air through hot liquid paratertiary butyltoluene in the presence of a metallic catalyst and can be adapted to other basic aromatic acids.

(More News on page 66)

heat exchangers BY Paracoil

provide sustained performance, rugged construction and an eye to operational accessibility for maintenance and repairs. We build well—our record of repeat orders from satisfied clients attests to that.

FOR THE CHEMICAL PROCESS INDUSTRY, WE OFFER OUR...

Solvent Recovery Equipment • Extraction Coils • Evaporators • Reaction Vessels • Condensers (for any Vapor) • Solution Heaters & Coolers • Exhaust Waste Heat Boilers • Quenching Oil Coolers • Storage Tank Heaters • Gas Coolers • Self-Cleaning Heat Exchangers • Fractionating Equipment

Your pilot plant or special equipment requirements can be handled by our experienced staff of chemical and mechanical engineers. We solicit your inquiries.

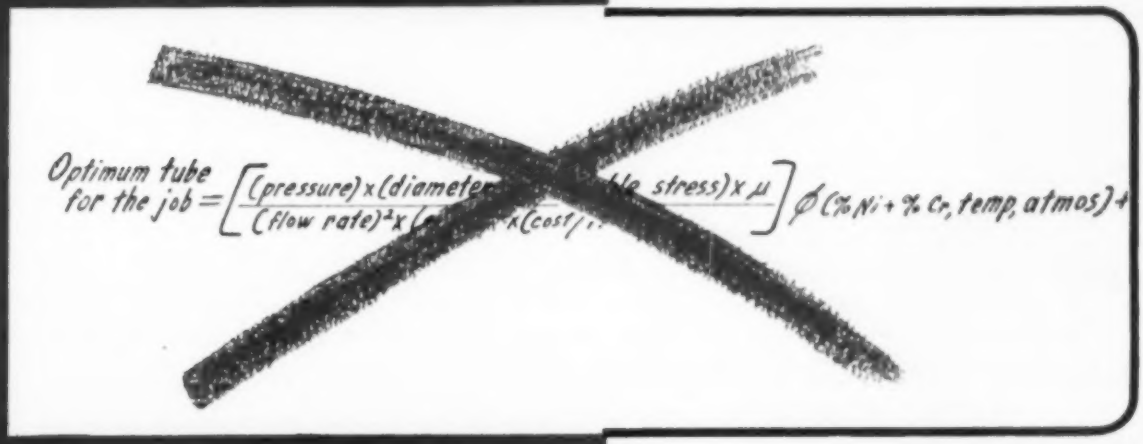
DAVIS ENGINEERING CORPORATION
1058 East Grand Street, Elizabeth 4, N. J.
30 Rockefeller Plaza, New York 20, N. Y.

WHEN PRESSURE IS PARAMOUNT

Tube Selection Cannot Be Reduced to a Formula—Even a Complicated One

The choice of the optimum tubing to use in an application requiring the handling of a specific fluid at a definite working pressure involves the consideration of a number of factors. In addition to temperature, tube size, and mechanical strength of the steel, such factors as the type of fluid and corrosion resistance of the steel must be considered.

A typical case of the importance of these two factors involved an installation of Type 347 stainless steel. The tubing was exposed to chloride-bearing bayou water while conveying methanol and unreacted synthesis gases at 300F and 5000 psi. The chloride solution caused pitting corrosion. The stresses became localized at the root of the pits and reached a sufficient magnitude to cause stress corrosion and failure. Croloy 5, subsequently used, provided superior resistance to the initial pitting and satisfactory service at the desired temperature and working pressure and also at a considerable savings in cost of the tubing.



B&W SEAMLESS and WELDED TUBES

THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION

It takes an expert to specify the optimum tubing for any particular application. And there is no substitute for the kind of experience with such problems you'll find at B&W. To get the most benefit from B&W's long experience in matching tubes to jobs call on Mr. Tubes, your nearby B&W Tube Representative. He can help you.

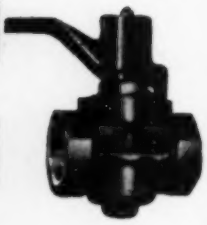
TA-4024 (P)

NO STICKING

NO GUMMING

NO FRICTION

NO LEAKAGE



AND NO CORROSION!

WHEN CORROSIVE CHEMICALS RUN THRU

DeZURIK VALVES

WITH TEFLON-FACED* PLUGS

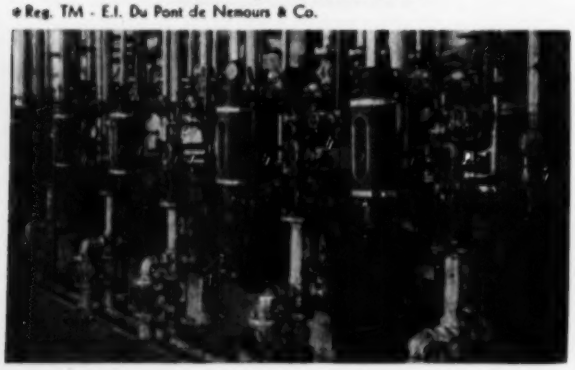
DeZURIK EASY-OPERATING PLUG VALVES have many proved advantages: They're friction-free, require no lubrication, open and close e-a-s-i-l-y every time. Now there's the extra advantage of TEFLON-Faced plugs, providing a valve for corrosive services that resists deterioration, can't distort and won't gum-up. There's a DeZurik Valve for every chemical situation — just ask for details.

DeZurik Valves with TEFLON-Faced Plugs are made in sizes from ½" thru 2", for manual operation, or for use with Air Operators' (illustrated). Valves with rubber-faced plugs up to 20" in size.

DeZURIK SHOWER COMPANY

SARTELL, MINNESOTA

* Reg. TM - E.I. Du Pont de Nemours & Co.



CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before September 15, 1954, at the Office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Aljian, George W., *San Francisco, Calif.*
Bourguet, John M., *Woodbury, N. J.*
Brown, Gardner L., *Akron, Ohio*
Coffey, Burton L., *New York, N. Y.*
DeLany, W. H., Jr., *Oak Ridge, Tenn.*
Dodson, John L., *Oak Ridge, Tenn.*
Dylewski, Stanley W., *Midland, Mich.*
Giachino, Marcello T., *New York, N. Y.*
Greene, John H., *New York, N. Y.*
Guess, Algernon P., *Camden, S. C.*
Gustafson, Edward L., Jr., *Kingsport, Tenn.*
Gutshaw, Kenneth J., *Charleston, W. Va.*
Hall, C. Robert, *Akron, Ohio*
Johnson, Homer F., Jr., *Knoxville, Tenn.*
Jones, Cyrus R., *Washington, D. C.*
Kelly, H. S., *New York, N. Y.*
Kern, B. M., *Pittsburg, Kan.*
Large, Charles B., *Sacramento, Calif.*
Merryman, G. E., Jr., *St. Albans, W. Va.*
Messina, Philip, *Linthicum Heights, Md.*
Moncrief, D. B., *Institute, W. Va.*

(Continued on page 64)

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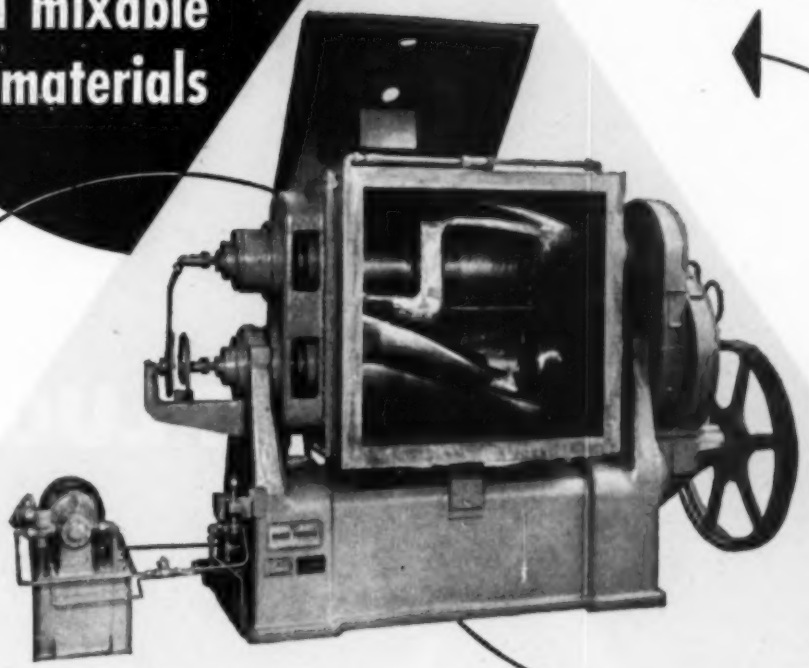
BAKER PERKINS

mixers for the rapid efficient mixing of all mixable materials



Size 16—JWIM BAKER PERKINS Universal Vacuum Mixer with overlapping cored Sigma blades and jacketed trough shell. Trough shell and cover are operated by a single control lever. 30 hp motor.

If it can be mixed, there's a BAKER PERKINS Mixer that will do the job thoroughly and efficiently. In capacities to suit your requirements, B-P Mixers can handle materials ranging in consistency from dry powders and light fluids to stiff plastic masses. Here are just a few of the products being made and the mixing and kneading operations now being successfully performed in B-P machines:

Foundry Sand	**Color Flushing**	**Rubber Dispersions**
Polyester-Fibers	**Plastics**	**Carbon Products**
Adhesives	**Food Products**	**Pigment Dispersion**
Floor Tile	**Plastisols**	**Chemical Reactions**
Carbon Electrodes	**Blending**	**Rubber Products**
Vacuum Drying	**Paint and Varnish**	**Dog Food**

BAKER PERKINS INC.

282

CHEMICAL MACHINERY DIVISION • SAGINAW, MICHIGAN

WHAT ABOUT CONTROL OF

FLASHING LIQUIDS?

THE ANSWER IS
THE ***EXCLUSIVE***

H---D

FLASH-FLO PLUG

Another Famous Hammel-Dahl First

ELIMINATES...

- DESTRUCTIVE VIBRATION
- TRIM DETERIORATION
- HIGH NOISE LEVEL

Interchangeable with standard trim in ½ or larger sizes

Complete Information in Bulletin 101-B

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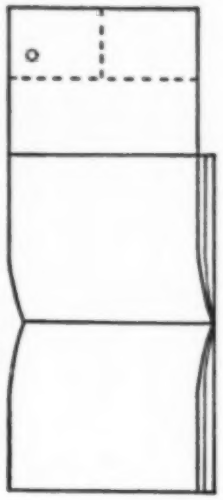
CANADIAN MANUFACTURING AFFILIATE—GUELPH ENGINEERING CO., GUELPH, ONT.

Visit our Booth 410-412, First International Instrument Exhibit—Philadelphia, September 13 thru 24.

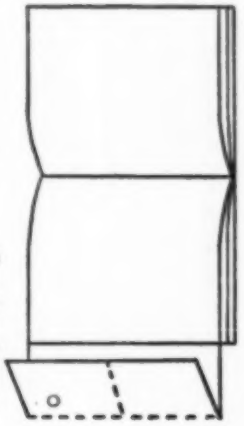
for your information

This C.E.P. information service is a convenient way to get the chemical engineering information you need on the new equipment, on advertised product, on the newly announced developments reported on these pags. A one post card inquiry designed to bring data quickly and easily. Circle the items of interest, sign your name, position, address, etc., and drop in the mail.

Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN . . . .



as you pass the pull-out page, and it is on the left, fold the post card back along the vertical scoring, and once again the numbers are handy for circling.



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First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

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CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

PRODUCTS

IFC **Louisville Cooler.** Surface coolers, water tube coolers, and atmospheric coolers.
Louisville Drying Machinery Unit, General American Transportation Corp.

3R **Barrel and Drum Packer.** Capacities of from 5 to 1,000 lb. Other models used for packing bags weighing up to 150 lb.
B. F. Gump Co.

4A **Centrifugal Pumps.** Made of "Karbate" impervious graphite, also heat exchangers, towers etc.
National Carbon Co.

6L **Laboratory Stirrer.** Direct and gear drive, fully enclosed ball bearing motor. Ranges from 400 rev./min. to 5,000 rev./min. in stepless control.
Ace Glass, Inc.

7A **Crystallization Equipment.** Shop view of unit 50 ft. high and 11 ft. 3 in. in base diameter. Crystal appearance also shown.
Struthers Wells Corp.

8L **Process Plants.** Specializing in plants for: fats and oils, fatty alcohols, resins, soaps and detergents, etc.
Industrial Process Engineers

9A **Lapp Pulsafeeder.** Pumping rate is controlled by instrument air pressure responsive to variable flow, pH, temperature, liquid level, pressure, or any other instrument-measurable processing variable.
Lapp Insulator Co., Inc.

10A **Filters.** Standard drum continuous vacuum filters.
The Eimco Corp.

11A **Synthol.** The Kellogg-developed process for catalytically reacting synthesis gas to produce hydrocarbon materials and chemicals.
The M. W. Kellogg Co.

12L **"Rubberhide" Linings.** Compounded from rubber or neoprene to provide resistance to specific corrosive agents.
Goodall Rubber Co.

13A **Diaphragm Control Valves.** Type Y continuously connected side handwheel for emergency manual control.
Black, Sivalls & Bryson, Inc. Climax Controls Div.

14A **Valves.** 125-lb. iron body wedge gate equipped with Crane 18-8 SMo stainless steel trim.
Crane Co.

15A **Radiant Heat Furnace.** Can be brought to fully effective operation in five minutes.
Blaw-Knox Co., Chemical Plants Div.

16A **Rubber Expansion Joints.** Made in all pipe sizes from ¾ in. to 72 in. Round, rectangular, tapered or offset.
The Garlock Packing Co.

17A **Complex Fertilizer.** Complex fertilizer by a continuous process. Will provide a complete, integrated plant. Can now license Commercial Solvents' Stengel Reactor.
The Chemical & Industrial Corp.

18A **Insulation.** Explains how company saves fuel, reduces maintenance on outdoor tanks with insulation.
Johns-Manville

19A **Processes and Plants.** Features vinyl chloride monomer plant built by Girdler.
The Girdler Co.

20L **Aero After Cooler.** Cools a compressed gas, or air, below the temperature of the surrounding atmosphere, preventing the condensation of moisture in lines.
Niagara Blower Co.

21A **Process Engineers.** Services for the atomic energy, chemical, petrochemical and oil refining industries.
Catalytic Construction Co.

22A **Vacuum Drying Chambers.** Production method for removing water and recovering valuable solvents safely.
F. J. Stokes Machine Co.

23A **Acetylene Derivatives Plant.** The first commercial installation in this country for the manufacture of acetylene derivatives based on Reppe Chemistry.
Lummus Co.

24L **Teflon Packing.** For use in manual, air or motor operated valves.
United States Gasket Co.

25A **Valves.** For chemical resistance qualities. Porcelain-to-porcelain seal.
Lapp Insulator Co., Inc.

26A **Celite Filtration.** Nine standard grades. Microscopically controlled particle size. For removal of insoluble impurities from water, petroleum, chemicals, etc.
Johns-Manville

27A **Ammonia Synthesis.** Casale ammonia condenser, deoxidation reactor and converter. Designed, constructed and licensed by
Foster Wheeler Corp.

28L **Process Piping.** Engineering guidance and manufacturing.
Badger Mfg. Co.

29A **Stainless Steel Products.** Stainless steel castings, valves and fittings.
The Cooper Alloy Foundry Co.

30A **Haveg Stacks.** 200 ft. high with a 4 ft. diameter. Also towers, tanks, piping, valves, etc.
Haveg Corp.

31A **Heat Transfer Medium.** Single vaporizer serves several consuming points with different temperatures at the desired degree.
The Dow Chemical Co.

32A **Proportioning Pumps.** Complete, self-contained and ready to operate.
Proportioneers, Inc., Division of B-I-F Industries, Inc.

37BA **Tubing.** Flexible, plastic pipe, in sizes up to 2 in. I.D., used as temporary or permanent acid and alkali lines.
U. S. Stoneware Co.

39A **Gasholders.** Dry fabric seal eliminates maintenance problems.
Wiggins Gasholder Div., General American Transportation Corp.

41A **"Meter that Pumps."** Positive displacement metering. No frictional parts in liquid end. Capacity range: 5 cc. to 6 gal./hr., 2,500 to 10,000 lb./sq.in.
Hills-McCanna Co.

43A **Pulverizers.** For the processing of sugar. Also for the processing of chemicals, pharmaceuticals, cosmetics, soaps, fertilizers, and plastics.
Pulverizing Machinery Div., Metals Disintegrating Co., Inc.

44L **Ball Bearing Swivel Fittings.** Large fluid passageways reduce turbulence and increases flow. 8 basic styles—

Chemical Engineering Progress

Please do not use this card after November, 1954

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Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Advertisers' Products

IFC	3R	4A	6L	7A	8L	9A	10A	11A
12L	13A	14A	15A	16A	17A	18A	19A	20L
21A	22A	23A	24L	25A	26A	27A	28L	29A
30A	31A	32A	378A	39A	41A	43A	44L	45A
46A	48L	49A	50L	50R	51A	52L	528R	53A
54A	59A	63A	64B	65A	66L	67R	68L	69R
70L	71R	73R	74L	74R	75L	75R	76T	76BL
77T	77B	78L	79TL	79BL	79R	81T	81B	83R
84T	84B	85B	IBC	OBC				

Chemical Engineering Progress Data Service

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August, 1954

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Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

over 500 models.
Emsco Manufacturing Co.

45A **Rotary Kilns.** Oil fired units can be rotated at speeds ranging from 2 rev./hr. to 5 rev./min.
The C. O. Bartlett & Snow Co.

46A **Ratio Controller.** Regulates critical gas mixtures in carbon black production.
Minneapolis-Honeywell Regulator Co.

48L **Industrial Equipment.** Dust and fume eliminators, industrial ovens, spray booths, and mechanical washers.
Schmieg Industries, Inc.

49A **Graphite Electrodes, Anodes, Molds.** Features chlorine for refrigerants and other cooling operations.
Great Lakes Carbon Corp., Electrode Div.

50L **pH, Chlorine Tests.** Three steps give the determination; compact, portable. Color standards carry guarantee against fading.
W. A. Taylor and Co.

50R **Heat Exchangers.** Solvent recovery equipment, extraction coils, evaporators, reaction vessels, etc.
Davis Engineering Corp.

51A **Tubing.** Seamless tubing, welded stainless steel tubing, welded carbon steel tubing.
The Babcock & Wilcox Co., Tubular Products Div.

52L **Valves.** Teflon-faced plugs. Sizes from ½ in. thru 2 in., for manual operation, or for use with air operators.
DeZurik Shower Co.

(Continued on back of this insert)

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54A	59A	63A	64B	65A	66L	67R	68L	69R
70L	71R	73R	74L	74R	75L	75R	76T	76BL
77T	77B	78L	79TL	79BL	79R	81T	81B	83R
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☐ I want a subscription. Bill me $6.00 for a year.

August, 1954

PRODUCTS (*Continued*)

52BR **Instrument Congress & Exposition.** Sept. 13-24, Sept. 15-21 in Philadelphia. Send for invitation or further information.
The Instrument Society of America

53A **Mixers.** Can handle materials ranging in consistency from dry powders and light fluids to stiff plastic masses.
Baker Perkins, Inc.

54A **Flash-Flo Plug.** For control of flashing liquids. Eliminates destructive vibration, trim deterioration, and high noise level.
Hammel-Dahl Co.

59A **Chillers.** Provides chilled water for blending, mixing, external cooling or wherever required in processing operations.
The Patterson-Kelley Co., Inc.

63A **Pyrex Pipe.** Glass offers advantages of non-contamination, corrosion resistance, clear transparency, and light weight.
Corning Glass Works

64B **Flowrites.** Fiber plugs, guns and plugs, and bevel gear universal joints.
Condenser Service & Engineering Co., Inc.

65A **Zipper Conveyor-Elevator System.** For handling carbon black. Zipper belt teeth are automatically spread, meshed and locked by means of ball bearing rollers.
Stephens-Adamson Mfg. Co.

66L **Chlorination.** Slime control equipment designed for any need.
Wallace & Tiernan

67R **Wire Cloth.** Available in all the commercially used metals. Sizes ranging from 4 in. (space cloth) down to 400 mesh. Catalog E.
Newark Wire Cloth Co.

68L **Florite Desiccant.** Drying agent absorbs water from static or flowing system.
Floridin Co.

69R **Tantalum.** Used for most acid solutions and corrosive gases or vapors except HF, alkalis, or substances containing free SO_3. Free booklet.
Fansteel Metallurgical Corp.

70L **Vapor Condensers.** Standard stainless steel vapor condensers and thermosyphen reboilers.
Doyle & Roth Mfg. Co., Inc.

71R **Exhaust Fans.** Newly designed, 30% lighter than previous models.
The Duriron Co., Inc.

73R **High Alloy Castings.** Features a carburizing fixture for ball bearings 1½ in. diameter. Also a muffle for continuous strip annealing 12 ft. 6 in. long.
The Duraloy Co.

74L **Antifoam A.** Odorless and tasteless, silicone defoamer is physiologically harmless in foods at concentrations up to 10 parts per million. Also Antifoam AF, a dilutable defoamer containing 30% Antifoam A.
Dow Corning Corp.

74R **Motors.** Geared motor with solid shank pinion. Four to 10,000 R.P.M., ¼ to 30 hp.
U. S. Electrical Motors, Inc.

75L **Stacks.** For venting corrosive fumes—inside or out. Resin bonded glass fiber laminate.
The Chemical Corp.

75R **Pumps and Compressors.** Built-in valve automatically prevents reverse flow through compressor and also dampens pipe line pulsations.
Pennsylvania Pump & Compressor Co.

76T **Meters.** To deliver predetermined quantities for batching. For continuous blending of two or more liquids.
Bowser, Inc.

76BL **Stainless Steel Products.** Buckets, 8 in. pipe, Woodruff keys, pipe fittings, valves, cotter pins, nuts, wood screws, etc.
Schnitzer Alloy Products Co.

77T **Heat Transfer Equipment.** Extra-tight tolerances on tube fit. Fabricated from various grades of carbon steel, stainless steel, stainless and nickel alloy clad, etc.
Downington Iron Works, Inc., Division of Pressed Steel Tank Co.

77B **Spraco Nozzles.** Full cone, flat spray and hollow cone spray nozzles. Catalog.
Spray Engineering Co.

78L **Tricone Mills.** Correct ball segregation. Greater grinding volume. Low wear in discharge grate. Bulletin.
Hardinge Co., Inc.

79TL **Package Engineering.** Development of packaging materials and packages for any product.
Foster D. Snell, Inc.

79BL **Technical Data Books.** Condensed data for the student, engineer, technical worker and business man. Catalog.
Lefax

79R **Power Transmission Equipment.** Flexible couplings, variable speed pulleys, speed transmission, and universal joints.
Lovejoy Flexible Coupling Co.

81T **Proportioning Pumps.** 7,500, 15,000 or 30,000 lb./sq.in. working pressure by the interchange of piston and cylinder assemblies.
American Instrument Co., Inc.

81B **Filtering, Mixing, and Storing.** Filter, mixer, storage, and mixing tanks. Complete range of sizes and capacities.
Alsop Engineering Corp.

83R **Ammonia Catalysts.** To produce more ammonia without excessive expansion of existing facilities.
The Girdler Co.

84T **Bubble Caps.** Bulletin lists 200 styles. Special caps designed.
The Pressed Steel Co.

84B **Laboratory Ware.** Resistant to heat shock. For numerous analytical applications. Bulletin.
The Thermal Syndicate, Ltd.

85B **Evactors.** Illustration shows two 4-stage evactors in pharmaceuticals plant. Also jet mixers, jet heaters, etc.
Croll-Reynolds Co., Inc.

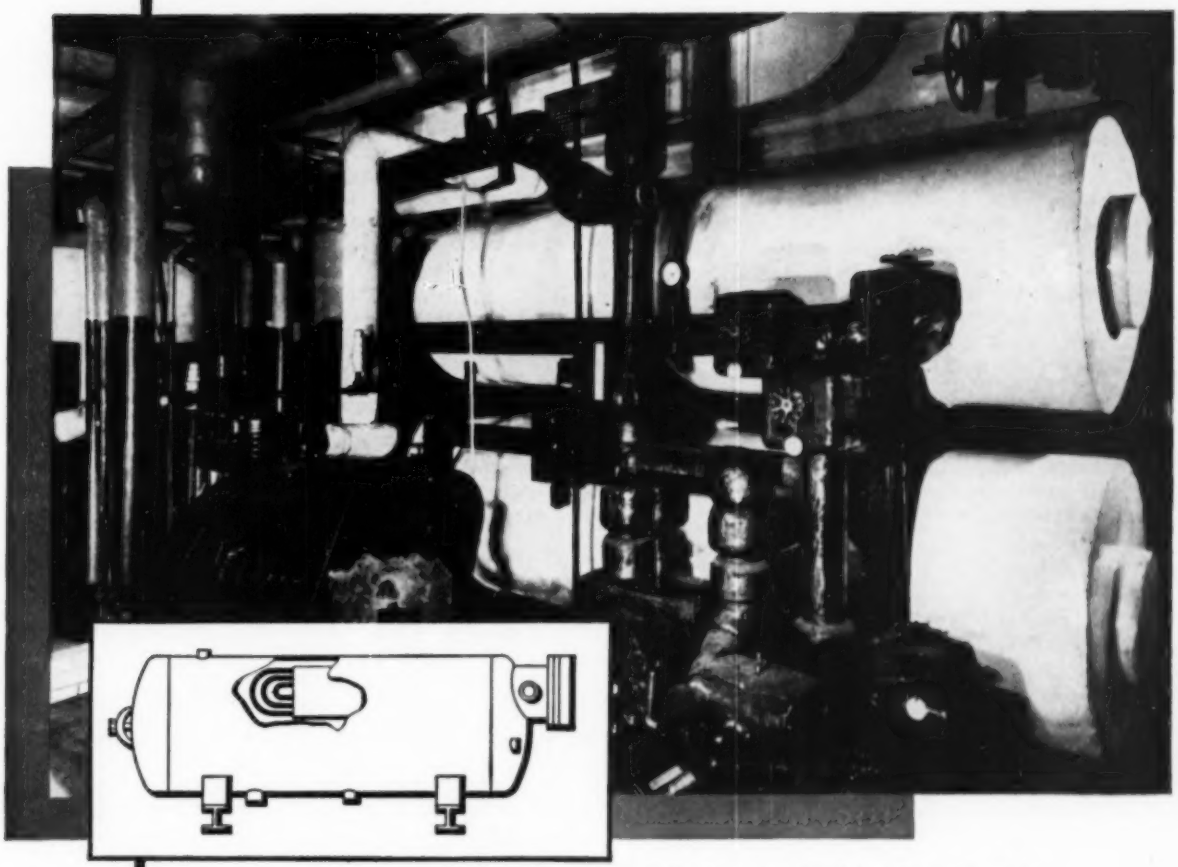
IBC **Engineering Service.** Process and plant design, equipment design and procurement, construction and erection.
The Vulcan Copper & Supply Co.

OBC **Mixing.** Calibrated impeller provides a basis for accurate speed-diameter-horsepower.
Mixing Equipment Co., Inc.

COLD WATER STRATEGY

for processing operations

-p·k *chillers*



A p·k chiller provides chilled water for blending, mixing, external cooling or wherever required in processing operations. p·k chillers feature a combination water storage tank and built-in chiller of corrosion-proof construction.

With this design, smaller chilling surface and refrigerator compressor capacity can be used and the load factor is improved. Individual water coolers are dispensed with and concentration of cooling facilities in one central location reduces initial investment and facilitates servicing. Fluctuating water requirements are easily met without temperature change. Any new or present compressor equipment can be used.

p·k storage water chillers are available in many sizes and in various kinds of materials to suit individual requirements. These same storage cooler units are applicable to any liquid cooling application, in process and other industrial plants.

Write today for illustrated literature and engineering suggestions. Ask for Catalog No. 101.

the Patterson-Kelley Co., inc.

1780 Lackawanna Ave., East Stroudsburg, Penn.

2518

101 Park Avenue, New York 17 • Railway Exchange Building, Chicago 4 • 1700 Walnut Street, Philadelphia 3 • 96-A Huntington Avenue, Boston 16 • and other principal cities

EQUIPMENT

1 **PVC Parts.** Duravin a PVC material is now available from Wilmington Plastics Co. as pipe, pipe fittings—threaded sizes ½ to 4 in., valves, blowers, nuts & bolts. Material is lightweight, resilient, corrosion-resistant, rigid & tough. Can be machined, threaded, drilled, sawed or welded. Bulletin gives properties, technical data, chemical resistance tables.

2 **Telemetering System.** System designed for automatic remote control of industrial water & waste equipment developed by Automatic Control Co. Provides transmission for thirty control or continuous proportional signals between transmitter & receivers to span distances between outlying deep wells, reservoirs, treatment basins, storage facilities & central control centers.

3 **Packaged Automatic Boiler Line.** Orr & Sembower, Inc. offers bulletin on Powermaster packaged automatic boilers for firing light oil or gas. Oil-firing equipment is a simplified mechanical pressure atomizing burner; for gas a special premixing gas burner is used. Combination units for gas or oil. Sizes 15 through 100 hp. covering steam requirements to 3,450 lb./hr. Also hot-water designs. Unit is a 3-pass boiler with single flue gas flow reversal at either end.

4 **Adjustable-Speed Drive.** The electronic Select-A-Spede developed by Louis Allis Co. is designed for a.c. power lines & available with d.c. drive motors in NEMA frame sizes ¾ to 15 hp. Speeds 5:1 to 100:1. Precision speed control; wide speed range available; adaptable to optional electrical & mechanical modifications.

5 **Acid Wagon.** Automotive Rubber Co., Inc. offers bulletin on acid buggy for handling corrosive chemicals with capacities to more than 400 gal. Equipped with Saunders-type rubber-lined valves plus four 50-ft. lengths of acid hose with nozzles, etc.

6 **Recording Controllers.** General Electric Co. presents bulletin on potentiometric & a.c. bridge recorders & controllers. Designed for continuous measurement & control uninterrupted by periodic standardization. Features a magnetic standard in potentiometric system & bridge-balancing unit in the a.c. bridge system. Either model available with electric or pneumatic control.

7 **Vacuum Dryer.** Called Conaform & developed by Patterson Foundry and Machine Co. new type vacuum dryer. Used by manufacturers of temperature sensitive & easily oxidizable materials. Design permits continuous material circulation during cone rotation. No internal moving parts.

8 **Weight Recorder.** From Omega Machine Co. redesigned & improved equipment for checking & recording rate of feed of volumetric feeders by loss-in-weight method. Compact, indicator scale shows content & refill point. A 24-hr. recorder charts in 50- or 100-lb. capacity records time of hopper reloading.

9 **Packless Valve.** Clifford Mfg. Co. announces bellows-type, packless valve designed for manual or pneumatic-hydraulic operation. All-metallic construction eliminates sliding or restrictive packings & insures positive leak tight seal minimizing wear & deterioration. Suitable for both high vacuum & pressure systems, mass spectrometers, etc. Pressures to 150 lb./sq.in. with adaptations for higher pressures.

10 **Gas Volume Meter.** Miniature gas volume meter from J. J. Monaghan Co., Inc. Accuracy within 5% in range of 5 to 65 l. flow rate/min.

11 **Separation Unit.** Magnetic separation unit utilizing permanent Alnico V magnets attached to pulley belt plus pulley belt introduced by Eriez Mfg. Co. Economical for separation of steel alloys from nonmagnetic materials.

12 **Weighing & Filling Machine.** Elec-Tri-Pak a semiautomatic weighing & filling machine from Triangle Package Machinery Co. Features high accuracy, weighs & fills to 20 packages/min., weight range 2 oz. to 5 lb.

14 **Straight Line Strainer.** Newly designed straight-line strainer from Hays Mfg. Co. protects appliances, equipment, valves, controls. Provides clean, uninterrupted flow of water, air, or gas. Eliminates unnecessary friction, loss & turbulence. Utilizes union couplings for easy installation & cleaning. Parts are noncorrosive. Sizes ¼- to 1-in. pipe sizes.

15 **Sump Pump.** Class JU pump with top discharge from Black-Clawson Co., Shartle Bros. Machine Division. No packing boxes above or below impeller. Seven sizes 3- to 12-in. diam.; discharge capacities 50 to 4,000 gal./min. Can be suspended in liquid or pump casing; can be grouted into sump bottom. Available in variety of materials suitable to use conditions.

16 **Liquid Level Control.** Photoswitch, Inc. announces level control said to be versatile & efficient. Universal for 115 or 230 v., 50- to 60-cycle supply.

17 **Circuit Load Error Reduction.** Latest edition of Keithley Instruments Engineering Notes describes techniques for reduction in circuit load errors. Also comparison charts & error magnitude information.

18 **Explosion Proof Housings.** Adalet Mfg. Co. announces manufacture of cast aluminum, explosion-proof housings for enclosing fuses, relays, starters, allied equipment operated in combustible atmosphere. Available for 2-in. conduit or smaller.

19 **Packaged Boiler.** Compact, packaged boiler model CB announced by Cleaver-Brooks Co. Unit is self-contained, for processing or heating, steam or hot water. Capacity 15 to 40 hp. Provides silent operation, low decibel ratings, burns light oil without difficulty. Four-pass construction.

20 **Selector Valve.** Perfected by Republic Mfg. Co. a balanced selector valve handling pressures to 6,000 lb./sq.in. with ease. Sizes ⅜ to 1 in. for 0 to 2,000 lb./sq.in. & ⅛ to 1 in. for 0 to 6,000 lb./sq.in. for most services; for air & gas, 0 to 1,000 & 0 to 3,000 lb./sq.in, respectively. Three types of portings.

21 **Metal Detector.** Dings Electronics, Inc. Bulletin announces an electronic metal detector built in two types for deep burden service such as mining. Embodies ultrahigh sensitivity—sensitive to all metals, ferrous or nonferrous, & said to detect even minute particles; protects against tramp metal damage. Variety of signal & reject arrangements available.

22 **Magnetic Grate.** Developed by Eriez Mfg. Co. permanent magnetic grate flexible in design permits hoppers of any shape to be easily fitted. Prevents shutdowns because of elimination of contaminating metal materials from passing from hopper into machine. Easily maintained.

23 **Magnetic Amplifiers.** Bulletin from Magnetic Amplifiers, Inc. summarizes in table form line of 60 & 400 centipoise magnetic servo amplifiers, lists amplifier systems & their

servo performance. Also available standard or specially designed magnetic voltage regulators for motor generator & motor alternator sets.

24 **Fireproof Hood.** For protection of firefighter's head, with built-in safety helmet available from Industrial Safety Specialties Co. Made of aluminized asbestos for greater heat deflection. Surface reflects more than 80% of heat. For protection against falling objects an adjustable hard safety hat is riveted in top of hood. Riveted aluminum frame holds ¼ in. laminated safety glass window 5 x 6¾ in. providing unobstructed view.

25 **Steam Cleaner.** Bulletin on portable Spontane steam cleaner from Turbo Machine Co. Converts cold water to 80 lb./sq.in. steam in 45 sec. Speed made possible by Hydro-Therm flow a patented preheating arrangement. Operates at 80 to 125 lb./sq.in. steam independent of city water pressure; automatic ignition, water level & pressure control.

26 **Flushing Filters.** Added to line of Homefilter Co., all bronze Por-O-Met reverse flushing filters. Application for 1- or 2-in. pipe connections. Remove suspended foreign matter & deliver clear liquid. Lifetime elements of sintered bronze, microporous porcelain, porous Alundum. Sizes for removing matter from 100 microns to .5 micron.

27 **Worm Gear Thrust Roller.** Manufactured by Rollaway Bearing Co., Inc. modified inner spacer sleeve of type SDT precision thrust roller bearing. Bronze inserts have been exchanged for one-piece high tensile sleeve of cast iron which, being homogeneous has uniform coefficiency of expansion, wears well, machines easily.

28 **Portable Power Supply.** Audio Products Corp. announces portable regulated power supply for use with their modular system electronic units. New unit is 15 in. × 4¾ in. × 7½ in.; weighs 11 lb. Output of 80 ma. + 300 v. d. c. 15 ma. — 150 r. d. c. & 8 amp. 6.3 v. a. c. connected to units by standard modular power plugs.

29 **Centrifugal Pump.** Announced by Deming Co. new end suction centrifugal pump. Sizes 1- to 5-in. discharge; capacities to 1,000 gal./min.; maximum heads to 250 ft. Available with electric motor or belt drive, or pump only. Illustrated binder insert bulletin covers materials of construction, performance tables & curves. For use with liquids, with lime, chips, etc.

30 **Variable Capacity-Variable Head Pump.** Allis-Chalmers Mfg. Co. new type ACAP variable capacity-variable head pump. Consists of internal bypass bolted to machined single-suction centrifugal pump. Capacity range 0 to full rating, on pumps to 35,000 gal./min. & heads from 15 to 100 ft. with other variations possible.

31 **Leakless Centrifugal Pump.** Chempump a seal-less centrifugal pump guaranteed to give leakproof service. Available from Chempump Corp. Motor rotor integral with pump impeller. Welded construction allows field dismantling & reassembly without loss in leakproof qualities. Outstanding for corrosive services.

CHEMICALS

35 **Fluorothene Resins.** Technical data book from Bakelite Co. on fluorothene resins, their properties, forms, fabrication. Digest of latest information portrayed in graphs, tables, text. Also recommendations on extrustion, injection & compression molding.

36 **Accelerators—Mineral Dressing Agents.** (36) Delayed
37 action accelerators are subject of booklet from Calco Division of American Cyanamid Co. Includes general data, charts, etc. (37) From the Mineral Dressing Dept. bulletin on reagents titled "Mineral Dressing Notes." Describes properties & applications of various chemicals used in ore benefaction processes. Flotation bibliography included.

38 **Chemical Lists.** From Arthur S. LaPine & Co. catalog listing laboratory & industrial chemicals in quantities from ounces to hundreds of pounds. Sections arranged according to application.

39 **Carbon Black.** Acheson Dispersed Pigments Co. offers abstract of research literature pertaining to carbon black protection of polyethylene, in new ADP technical bulletin. Particularly valuable to manufacturers of plastic pipe as well as wire & cable, since outdoor weathering protection of polyethylene is important.

40 **Ion Exchange.** Information available from American Water Softener Co. on dealkalization of boiler feed water, experiences with chloride anion exchangers, & capacity of exchange resins with new caustic chloride dealkalization system.

41 **Oils, Waxes & Greases.** Detailed bulletin on Apiezon oils, waxes & greases for high vacuum work from James G. Biddle Co. Also includes information on tachometers & speed indications, laboratory lamps, electrical testing instruments, laboratory equipment.

42 **Furan Base—Test Data on Coating Systems.** (42) Bulletin
43 from Carboline Co. features Furan flexible coatings. Increased resistance to acids, alkalies & solvents. (43) Comparison test data includes results on sixty coating systems of varied natural & synthetic origins subjected to sulfuric acid spray.

44 **Polyester Resin Cement Mortar.** Delrac Corp. announces new white, quick-setting polyester resin mortar for corrosion-resistant masonry. Available in liquid & powder for mixing when used.

BULLETINS

45 **Jacketed Fittings.** J. P. Devine Mfg. Co., Inc. bulletin covers jacketed pipe & fittings. Included are specifications, dimensional charts, tables. For use with various oils, resins, molten sulfur, & foods.

46 **Gravity & Power Units.** Complete line of package-handling conveyor equipment from Standard Conveyor Co. described & illustrated in bulletin. Available are roller conveyors, spiral chutes, slides, etc. Also live rollers, vertical & record lifts, chain belts, etc. Cross-sectional views, power data specifications on each unit.

47 **Measuring & Control Equipment.** From Simplex Valve and Meter Co., binder insert illustrated catalog on controllers, gauges, manometers, valves, venturi tubes. Many cross-sectional views, tables for dimensional data on each item, construction & installation information as well as other pertinent data.

48 **Electric Flow Meters.** Penn Industrial Instrument Corp. leaflet on the Hays-Penn friction free flow meter said to have highest accuracy based on null balance principle; float acts only as pilot; manometer available in three

constructions for 1,000, 1,500, or 2,500 lb./sq.in. operating pressure. Individually calibrated cams said to produce hairline accuracy, evenly divided flow chart, many schematic diagrams, tables, other data.

49 **Process Equipment.** Designed for the chemical & pharmaceutical industries and fabricated to individual requirements, metal equipment for processing. Leaflet illustrates individual items in line of Glasco Equipment Corp. Available in variety of materials.

50 **Process Equipment.** Vacuum & pressure impregnating equipment from J. P. Devine Mfg. Co.,, Inc. is described & illustrated in folder. Applicable to chemical & allied process industries. Features extra sturdy construction for long-continued trouble-free service.

51 **Thermal Conductivity Units.** Gow-Mac Instrument Co. leaflet on Ever-Tite units. Respired air & enriched oxygen studies have used Gow-Mac T/C cells successfully as have workers in fumigant gases such as methyl bromide & carbon tetrachloride. Eight filament bridges have outputs of 200% of those for the four filament bridges.

52 **Insulating Brick.** Harbison-Walker Refractories Co. revised bulletin on six types of insulating brick important to refractories users. Includes data on brick in classes from 1,600° F. to 3,000° F. Features a 2-page thermal data chart giving heat losses, heat-storage capacities, cold-face temperatures for insulated walls.

53 **Steam Boiler Protection.** Titled "Laying-Up Equipment," folder from Hall Laboratories, Inc., on subject of safeguarding steam boilers, turbines, other similar equipment when laid up during shutdowns. Suggests protective methods.

54 **Ball Valves.** Ball valves designed & engineered for use in water works in general industrial applications subject of bulletin from S. Morgan Smith Co. For working pressure of 150 lb./sq.in. with 125 lb./sq.in. ASA flanged. Lever moves rotor 90° to open or close valves. Accomplished by linkage from crosshead. Characteristics, diagrams, tables of sizes included.

55 **Jet Mixer.** Said to provide accelerated reactions, emulsify immiscible liquids, reduce particle size agglomeration, circulate evenly with no vortex. Information on sizes, capacities, operational theory, etc. in folder. Hermas Machine Co.

56 **Motor Selector.** A 12-page bulletin (B-2102) from Reliance Electric & Engineering Co., for use in choosing quickly Reliance squirrel cage induction motor for applications from 1 to 200 hp. Lists performance characteristics, construction features, other essential information.

57 **Filters.** Graver Water Conditioning Co. bulletin tells how filtration of water or other liquids for industrial use can be obtained simply, economically & efficiently by use of Graver diatomite filters. Said to save up to 50% in wash water over sand or anthrafilt filters. Schematic diagrams, illustrations, other descriptive material included.

58 **Replacement Valve Bodies.** Two types of replacement pinch valve bodies for flang d and slipover pipe types in rubber, neoprene, butyl, Buna S & N, also special compounding. Data sheet from General Rubber Corp.

59 **Mastic Coating.** Palladium Mastic Corp. of America type T coating is developed to prevent corrosion of metal surfaces by acid or alkaline fumes. Highly rustproof for use on structural iron work. Vapor sealing & impervious to moisture. Employs Gilsonite as base, with asbestos & other inert mineral fillers.

60 **Spectrophotometer.** Perkin-Elmer Corp. illustrated brochure on features & advantages of double-beam model 21 infrared spectrophotometer. May be run routinely or under varied operating schedules. Flexibility in resolution programs, scanning speeds, response times, spectra presentation & recording speeds. Specifications, other data.

61 **Grinding Laboratory Service.** Illustrated bulletin from Rietz Mfg. Co. on laboratory services available for testing applications of size reduction, continuous mixing & dissolving & heat exchange equipment. Testing units can be installed for actual production on trial-rental plan basis. Testing done without charge.

62 **Control Instruments.** Thermoelements of noble & base elements are discussed in folder from Chas. Englehard, Inc. Also thermocouple protection tubes, available in ½- ¾- & 1-in. pipe sizes, any desired length with one end threaded, one closed. Each type fully described with tables, other information.

63 **Conveying Data Book.** Continental Gin Co. engineering data book ID-541 now available on screw conveyors. Various sizes & types with line drawings & dimensions. Includes standard, also unusual types & their applications.

64 **Plug Valves.** Binder insert reference book 39-sections, from Homestead Valve Mfg. Co. on lubricated plug valves in full-port & venturi types, sizes to 14 in. with choice of self-sealed two-piece or one-piece plug designs. Also pertinent engineering information. Section 5-A covers line of lubricants.

65 **Compressors & Vacuum Pumps.** Operation & construction of Allis-Chalmers Mfg. Co. single-stage water-cooled rotary compressors & vacuum pumps for air or gas handling requirements listed in bulletin. Cites economy reasons, covers construction & general specification details.

66 **Handling Systems.** Bulletin 400 from Gifford-Wood Co. illustrates specific industrial examples of material-handling systems. Technical information, section on mechanical methods for transfer & feeding of bulk materials, ilustrations & text on nine types of elevators, conveyors & feeders.

67 **Alloy Castings.** Titled "Heat Resistant and Corrosion Resistant Alloy Castings in Industry," illustrated bulletin from International Nickel Co., Inc. Compiled for users of stainless & heat-resistant alloys in cast form. Charts compare creep strength of various alloys, resistance to corrosion in certain media, & to oxidation at high temperatures. Tables of composition list principal Alloy Casting Institute designations, also certain proprietary alloys.

68 **Engineering Services.** Brochure on services offered by Barnes & Reinecke, Inc. Range from design, engineering & testing of processing equipment to special machines.

69 **Diaphragm Slurry Pumps.** Having no stuffing box, packing, motor, high-speed-moving parts Oliver United Filters, Inc. diaphragm slurry pump requires no delicate adjustments. Handles varied slurries & abrasive solutions both hot & cold. Bulletin 309-R available.

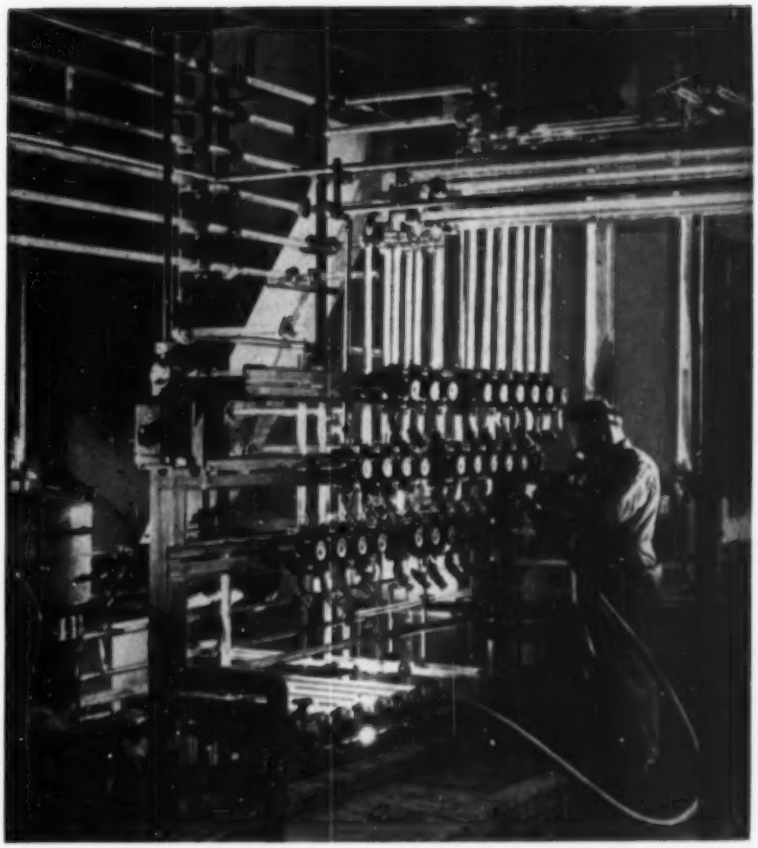
70 **Metering & Proportioning Pumps.** K-type reciprocating hydraulic drive metering & proportioning pump is subject of folder from Hills-McCanna. Explains operation, illustrates design features, gives complete capacity & pressure information on entire line. K-type is completely enclosed in-line, direct acting.

This PYREX® pipe "Switchboard" does an unusual materials handling job

If you toured the pilot plant of Merck & Co., Inc. in Rahway, N. J., you'd see this glass pipe "Switchboard" in action . . . speeding the progress of new products from research toward early production.

The system is constructed of one- and two-inch PYREX brand "Double-Tough" glass pipe arranged in circuits much like a telephone switchboard. Operators direct flow from various origins to a number of widely separated destinations just by adjusting valves located in pipe manifold stations similar to the one illustrated here.

This system provides the flexibility needed in handling the transfer of a constantly changing variety of chemicals from one processing stage to another. And Merck has constructed its PYREX pipe switchboard system so that it is instantly adaptable to handling materials with greatly different production cycles.



Operator at one of Merck's PYREX pipe "Switchboards" can cross-connect any of the glass pipelines in the manifold bank easily and quickly. The pipes are easy to clean and can be quickly switched to handling any number of different chemicals.

But why PYREX pipe?

Merck chose PYREX pipe for this complicated installation because only glass offers them all four of these necessary advantages:

1. *Non-Contamination*—PYREX pipe is chemically stable. It won't react with or contaminate the contents of the pipeline. It protects product purity.
2. *Corrosion Resistance*—PYREX pipe remains corrosion free even under the severest chemical service. It is unaffected by all acids except hydrofluoric.
3. *Clear Transparency*—Affords complete inspection at any and all points at all times. Trouble can't hide behind glass.
4. *Light Weight*—PYREX pipelines require a minimum of support.

Easy to clean . . . in place

A detergent run through PYREX pipelines followed by water or low pressure steam flushing, or both, generally removes all traces of past contents.

And PYREX brand "Double-Tough" glass pipe is durable. Experienced users report no breakage problems . . . even with operating temperatures as high as 250°F. In addition, PYREX pipe can be installed by regular plumbers or pipefitters.

Let us show how PYREX pipe can help you

Perhaps this Merck installation suggests some PYREX pipe application for your plant where greater corrosion resistance, improved product purity, or visual inspection can reduce your operating costs or give you closer quality control. Why not discuss your problems with the nearest PYREX pipe representative—or mail the coupon below for personal attention or further information.

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Scientific Supplies

Corning means research in Glass

CORNING GLASS WORKS
28 CRYSTAL ST., CORNING, N. Y.

Please send me the printed information checked below.
"PYREX brand 'Double-Tough' Glass Pipe and Fittings" (EA-3) ☐ (A complete catalog)
"PYREX brand Glass Pipe in the Process Industries" (EA-1) ☐ (picture-page, of successful installations) "PYREX brand Cascade Coolers" (PE-8) ☐ (A catalog)
Please have a PYREX pipe sales engineer get in touch with me ☐

Name.....
Company.....
Street.....
City..... Zone.... State.....

CANDIDATES *(Continued from page 64)*

Mooma, F. M., *San Francisco, Calif.*
Mroz, Edmund A. J., *Malden, Mass.*
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O'Keefe, Joseph A., *Wilmington, Del.*
Pizzirani, Donald A., *Alcala, Madrid, Spain*
Roudabush, H. Glenn, *Bristol, Pa.*
Schramm, Lester W., *Rifle, Colo.*
Spence, Sydney P., *Bloomfield, N. J.*
Steiner, Walter T., *Nutley, N. J.*
Unson, Miguel R., *Manila, Philippines*
Wharton, John, *Mobile, Ala.*
Wunn, Merlin O., *Willow Grove, Pa.*

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Arceneaux, Webster J., Jr., *Mobile, Ala.*
Arnold, H. K., Jr., *Baytown, Tex.*
Backstrom, Frank M., *Fayetteville, Ark.*
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Bishop, Truman B., *Midland, Mich.*
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Boggs, Richard L., *Middletown, Ohio*
Briggs, D. B., Jr., *Memphis, Tenn.*
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Brown, Richard C., *Spiceland, Ind.*
Brutvan, Donald R., *Troy, N. Y.*
Buck, James N., *Chicago, Ill.*
Cagnetta, John P., *Brooklyn, N. Y.*
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Cole, Robert, *Devon, Conn.*
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Costner, Thomas E., Jr., *Fultondale, Ala.*
Cox, Robert P., *Warrenton, Va.*
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deVries, Egbert, *Washington, D. C.*
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Gartner, David H., *Columbus, Ohio*
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Gluckstein, Martin E., *Ann Arbor, Mich.*
Goldman, Max, *Buffalo, N. Y.*
Goldstein, Lester, *Brooklyn, N. Y.*
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Hellwig, Langley R., *Austin, Tex.*
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Hopper, James S., *Newark, Del.*
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Johnson, Rolland E., *Roscoe, Ohio*
Jones, Bill M., *Little Rock, Ark.*
Kawasaki, Edwin P., *Cleveland, Ohio*
Kedl, Robert J., *Oak Ridge, Tenn.*
Kelley, Walter Harvey, *Wheat Ridge, Colo.*
Kivlen, John A., *Brooklyn, N. Y.*
Korosh, Stephen, *Williston Park, N. Y.*
Kovary, Eugene Joseph, *Jersey City, N. J.*
Kozel, William J., *Cleveland, Ohio*
Lance, Robert, *Chicago, Ill.*
Leist, Nelson R., *Norwood, Ohio*
Lempert, Frank L., *Pittsburgh, Pa.*
Leyse, Carl F., *Idaho Falls, Idaho*
Lightcap, Edward H., *Bellmawr, N. J.*
Lojek, Joseph M., *Ambridge, Pa.*
Lott, John O., *Avon Lake, Ohio*
Lyon, Richard E., Jr., *Bloomfield, N. J.*
Mathews, Richard C., *Whiting, Ind.*
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McCarty, William H., *Drexel Hill, Pa.*
Minderman, Peter, *Port Clinton, Ohio*
Mitchell, Ralph I., *Columbus, Ohio*
Mohan, Alfred E., *Philadelphia, Pa.*
Moody, L. Gilbert, *Vincent, Ohio*

(Continued on page 66)

CONSECO SPECIALTIES.... make your plant run Smoother

Flowrites of various sizes

Air erosion of tube inlets can be combatted by Flowrites, sometimes called "inserts" or "wearing sleeves." Flowrites serve as a replaceable wearing section and are fitted to the inlet ends of tubes.

Fiber Plugs

The right type of tube plug will eliminate many operating difficulties. Only fiber plugs have proven completely satisfactory. In stock for all standard tube sizes.

The "Conseco" Specialties shown here are a few of the many we have developed to simplify maintenance, reduce costs and step up performance in your steam plant. We carry these items in stock in standard sizes for prompt delivery, or special sizes can quickly be made to order. Descriptive Bulletins sent on request.

"CONSECO" PRODUCTS AND SERVICES

Retubing
Condensers
Evaporators
Air Ejectors
Heat Exchangers
Flowrites
Tube Plugs
Conco Plug and Guns
Bevel Gears
Instrument Repair Service
Blackburn-Smith Filters and Grease Extractors
Metal Spray

Bulletin Available for Above Items

Conco Gun and Plugs

For slime, algae, vegetable matter or soft flaky scale deposits, use the hydraulically operated Conco Gun and Plug. Can be fitted with adapters and plugs for any size tube.

Bevel Gear Universal Joints

Bevel Gear Universal Joints are designed and built to give positive transmission of torsion regardless of shaft angle. A simple, flexible and economical solution to the problem of shaft line-up.

CONSECO Condenser Service & Engineering Co., Inc.

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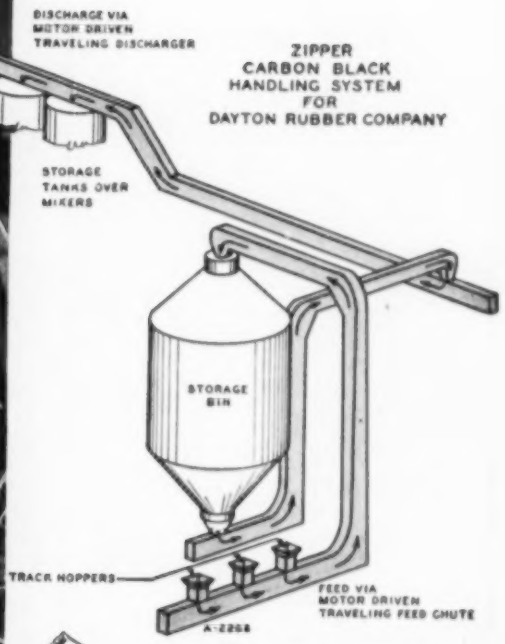
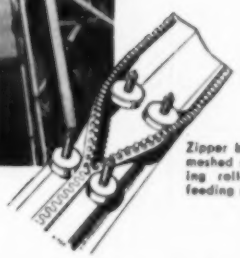
General view of S-A Zipper Conveyor-Elevator System for handling carbon black. Since the Zipper units operate in the open, they are protected from the weather by steel casings.



Sketch illustrates flow of carbon black through storage to processing via three ZIPPER belt conveyor-elevators. Note unit feeding from track hoppers which operates in two planes.



Zipper belt teeth are automatically spread, meshed and locked by means of ball bearing rollers as the belt travels past the feeding station.

Push Buttons Route Carbon Black Through Dust-Tight Zipper Distributing System

Remote control plus complete mechanization keynotes this conveying and storage system at the Dayton Rubber Company's Dayton, Ohio plant. Push buttons replace bag handlers — a single operator at a centralized control panel directs the 7-ton-per-hour flow of carbon black from hopper bottom rail cars, through storage, reclaiming and delivery to mixers in the plant.

Besides eliminating the excessive cost of handling the carbon black in bags, the system has greatly reduced degradation of the pelletized black and has practically done away with dust.

Incoming cars are spotted over the Zipper storage conveyor, which feeds from each one of the three track hoppers progressively selected at the control panel. At the 8-compartment storage bin, a motor driven swivel spout directs the flow of black to the proper compartment. In reclaiming, from storage, a Zipper Conveyor-Elevator discharges to a 238-foot Zipper that provides selective filling of the mixer storage bins.

If you have a dust or degradation problem, find out how much an S-A Zipper System offers you. Send for full data now.

STEPHENS-ADAMSON MFG. CO.
57 Ridgeway Avenue, Aurora, Illinois
Los Angeles, Calif., Belleville, Ontario

Engineering Division	Specialists in the design and manufacture of all types of bulk materials conveying systems.
Standard Products Division	A complete line of conveyor accessories including centrifugal loaders—car pullers—bin level controls—etc.
Sealmaster Division	A complete line of industrial ball bearing units available in both standard and special housings.

STEPHENS-ADAMSON MFG. COMPANY
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Please send us Bulletin No. 349 on ZIPPER Conveyors

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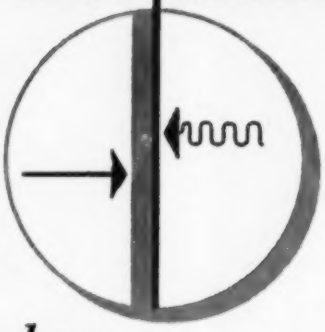
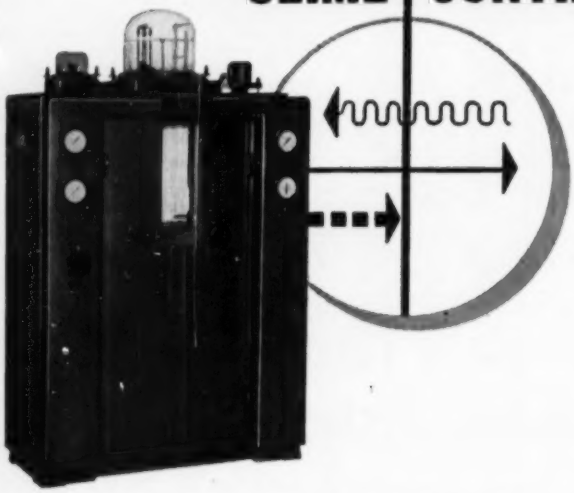
Where you need

HEAT | EXCHANGE



Be sure you have

SLIME | CONTROL



Whether you heat or cool water for make-up, process or any other use, you will need Wallace & Tiernan Chlorination to help combat slime problems introduced by water-borne bacteria or air-borne bacteria.

With slime control equipment designed for any need, built for lasting and dependable service, highly accurate and backed by over 40 years of successful application experience, Wallace & Tiernan Chlorination can help you increase the efficiency of your plant and cut operating costs. For further information write our Industrial Division.

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CD-39

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(*Continued from page 64*)

Mukai, Taro, *Seabrook, N. J.*
O'Brien, Noel G., *Louisville, Ky.*
Oliver, Mario H., Jr., *Caracas, Venezuela*
Pasbalis, Alexander W., *Cincinnati, Ohio*
Picou, Courtney F., *New Orleans, La.*
Planchet, Robert Jules, *New Orleans, La.*
Plywaski, William, *Troutdale, Ore.*
Post, George A., *New York, N. Y.*
Price, Harold G., Jr., *Salt Lake City, Utah*
Rabinowitz, Allan C., *Brooklyn, N. Y.*
Ragofsky, Howard, *Brooklyn, N. Y.*
Rhoden, Edgar I., *Buffalo, N. Y.*
Roberts, John W., Jr., *Columbus, Ohio*
Robirds, Kenneth D., *El Dorado, Ark.*
Robinson, Chester D., *Columbus, Miss.*
Roe, Sheldon F., Jr., *Elmira, N. Y.*
Saffell, Marlin Kay, *El Dorado, Ark.*
Salonga, Luz C., *Diliman, Q. C. Philippines*
Sanghvi, Manoj D., *Columbus, Ohio*
Say, Manuel B., *Cleveland, Ohio*
Scharfenberger, Gerald K., *Louisville, Ky.*
Schilling, Fred P., *Idaho Falls, Idaho*
Seeley, Donald C., *Verona, N. J.*
Selak, Patrick J., *Augusta, Ga.*
Semonian, Suren A., *Joliet, Ill.*
Shappert, Lawrence B., *Belvidere, Ill.*
Sivori, John H., *Bloomingdale, N. J.*
Smith, Marvin F., Jr., *Wilmington, Del.*
Sperry, William T., Jr., *North Plainfield, N. J.*
Sprout, William H., *Zanesville, Ohio*
Stearns, Bill B., *Little Rock, Ark.*
Stickle, Fred O., *Leonia, N. J.*
Stone, Gordon E., *Hammond, Ind.*
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Swartz, William E., *Harrisburg, Pa.*
Taylor, William F., *Akron, Ohio*
Ten Eyck, Peter A., *St. Petersburg, Fla.*
Thacker, Charles C., Jr., *Portsmouth, Ohio*
Tomzhinski, Armando, *Rio de Janeiro, Brazil*
Tostevin, W. C., *Hamilton, Ontario*
Toth, Edward Ralph, Jr., *Cleveland, Ohio*
Vamos, James E., *Cleveland, Ohio*
Vardaman, D. A., *Port Arthur, Tex.*
Veley, Floyd A., *Leonardsburg, Ohio*
Vaughan, A. E., Jr., *Cleveland, Ohio*
Waggner, Charles Edwin, III, *Baltimore, Md.*
Weidman, R. J., *Memphis, Tenn.*
Weiser, Robert Bruce, *Wilmington, Del.*
Willauer, David E., *Haddonfield, N. J.*
Wirtz, Lynn, *Little Rock, Ark.*
Wolffe, Franklin D., *Washington, D. C.*
Yaeger, A., *New Orleans, La.*
Yerina, James A., *Norwood, Ohio*
Ziemann, Carl N., *Cleveland, Ohio*

CHEMPUMP HAS UNDERWRITERS' RATING

Chempump Corp. has announced that its sealless centrifugal pumps have been listed by Underwriters' Laboratories for explosion-proof operation. They are possibly the first centrifugal pumps to have this rating on both pump and motor. The pumps afford Class 1 Group D protection for pumping solvents and light hydrocarbons at capacities to 180 gal./min. and at heads to 90 ft.

ENGINEERING BOOKS NEEDED IN FORMOSA

The need for technical literature, particularly on chemical engineering and chemistry, on the part of engineers in free China has been stressed recently by Thomas C. Doody, adviser in chemical engineering to the Taiwan College of Engineering in Formosa. Although a number of books and periodicals have been sent through the efforts of the Engineers Joint Council, the need is still great at the two major technical schools on the island. Anyone who can contribute needed material may address Dr. Doody at F.O.A. Mission to China, A.P.O. 63, Postmaster, San Francisco, Calif.

COMBUSTION INSTITUTE FOUNDED

The Fifth Annual Combustion Symposium, to be held from Aug. 30 through Sept. 3, 1954, at the University of Pittsburgh, will launch the new Combustion Institute, an outgrowth of the Standing Committee on Combustion Symposia. The interests of this new organization, according to its officers, embrace a field of scientific activity not covered by the meetings of established societies, although it cuts across many scientific and engineering disciplines.

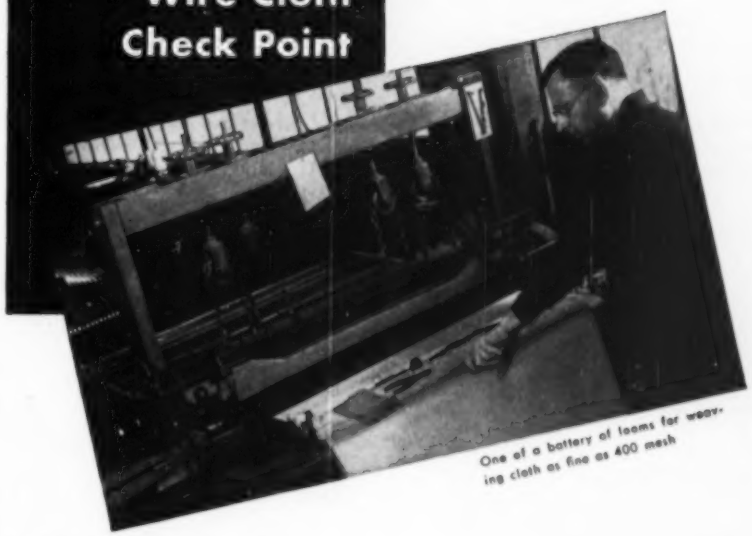
The institute will have an international committee that will be responsible for organizing and conducting the symposia of the institute and the publication of papers. Further information may be obtained from the institute at the Alcoa Building, Pittsburgh 19, Pa.

INDUSTRIAL MEETINGS ON THE INCREASE

In the constant battle for better and quicker communications among engineers working in rapidly expanding fields a number of companies have instituted meetings of one to three days' duration to which interested industrial personnel are invited to hear papers on a particular subject and to participate in discussion groups.

Typical of these meetings was a high-pressure-equipment clinic held by Autoclave Engineers, Inc., in their Erie, Pa., plants on June 21 and 22. Thirty research officials from Midwestern industrial organizations discussed problems in technique and listened to a talk on experiments being pursued at the University of Illinois in gaseous diffusion, thermal diffusion, liquid diffusion, and solubility under high pressures by Harry G. Drickamer, professor

An Important Wire Cloth Check Point



One of a battery of looms for weaving cloth as fine as 400 mesh

Weaving Precision

Our skilled workmen and precision looms combine to make precision wire cloth that meets the most rigid specifications. All shute wires are parallel and all warp wires are parallel as they must be, to assure a uniformly woven cloth with no defects. One or two open spots in a wire cloth could completely spoil the most painstaking screening operation.

In addition to its uniformity and freedom from imperfections, Newark Wire Cloth is noted for accurate mesh counts. Available in all the commercially used metals, Newark Wire Cloth is woven in sizes ranging from 4 inches (space cloth) down to 400 mesh.

We maintain a large stock of the commonly used metals and sizes, and are in a position to make prompt shipments. Let us quote on your requirements. When writing, please give us details on your process.

Send for our New Catalog E.

NEWARK for ACCURACY

Newark Wire Cloth COMPANY

351 VERONA AVENUE • NEWARK 4, NEW JERSEY

of chemical engineering at the university.

Earlier in the year, from Apr. 27 to 29, a meeting on corrosion in the chemical process field was held at The International Nickel Co.'s Harbor Island testing station. Stress and velocity effects on corrosion were considered, as was high-temperature corrosion, and a session was devoted to questions from the chemical engineer guests.

Among similar meetings held this year have been a three-day conference on corrosion-resisting process equipment, also in April, offered by The Pfaudler Co., Rochester, N. Y., to representatives from chemical, engineering, and instrumentation firms, and one by Cooper Alloy Foundry Co. of Hillside, N. J., which on June 24 reviewed for design engineers in various industries the latest developments in alloys and the use of shell molding and cast-weld construction.

THREE A.E.C. CENTERS TO INFORM INDUSTRY

Stanford Research Institute, Stanford, Calif., and the John Crerar Library in Chicago have been named by the Atomic Energy Commission as national industrial information depositories of unclassified atomic-energy information, in addition to the previously announced Atomic Industrial Forum of New York. They have been established to cover the western and midwestern states and Hawaii and Alaska and will receive new unclassified reports of special interest to industry and reproducibles of engineering drawings as they become available from the Atomic Energy Commission.

AID TO ENGINEERING FILES OFFERED

A list of references for the organization of files in engineering offices and libraries is available from the Engineering Societies Library. Covering classification and indexing and use of hand-sorted punched-card systems for engineering books, notes, correspondence, abstracts, drawings, etc., the mimeographed list contains seventy-nine annotated references and is available from the library at 29 West 39 St., New York 18, for two dollars.

A.E.C. TO BUILD HEAVY-PARTICLE ACCELERATOR

Construction of two heavy-particle accelerators, one at Yale University and one at the University of California Radiation Laboratory, has been authorized by the Atomic Energy Commission, which will contribute $1,200,000 to each project. Most particle accelerators built to date utilize relatively light particles. The new accelerators will accelerate atomic nuclei ranging from beryllium, with an atomic weight of 9, to neon, with an atomic weight of 20. Both machines will be linear accelerators, accelerating nuclei to an energy of approximately 10 million electron volts for each particle in the nucleus, power sufficient to allow the nuclei to interact with even the heaviest known elements.

The accelerator at California will be used primarily in nuclear chemistry studies, such as the possible production and identification of new elements and new isotopes of known elements. The Yale unit will be used in studies of the physics of heavy-particle nuclear reactions.

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ENGINEERS LAUNCH TECHNICAL REGISTER

Registration of engineers for the National Register of Scientific and Technical Personnel will be conducted by the Engineers Joint Council, according to a recent announcement by the National Science Foundation, which has made two grants for the registration of chemical engineers and chemists.

The engineering section of the register will be limited to about 20,000 leaders among the estimated 500,000 engineers in the United States. To be based on *Who's Who in Engineering* and other sources, the list will constitute a "finder's list" to provide an effective means of locating engineers for special projects. The list will be maintained by E.J.C.

Questionnaires are currently being mailed by the American Chemical Society to about 50,000 chemists, and it is expected that eventually some 65,000 chemists will be included in the register. Other professional societies collecting registration information are the American Institute of Biological Sciences, 40,000 registrants; Federation of American Societies for Experimental Biology, 10,000; American Veterinary Medical Association, 14,000; American Geological Institute, 18,000; American Psychological Association, 11,000; American Institute of Physics, 15,000; American Meteorological Society, 10,000; American Mathematical Society, 12,000.

LUKE SUCCEEDS BECKERLEY AT A.E.C.

Charles D. Luke, chairman of the department of chemical engineering at Syracuse University, will succeed James G. Beckerley as director of the office of classification, Atomic Energy Commission. Dr. Beckerley is resigning on Aug. 31, 1954, to return to private industry. He has been with the Atomic Energy Commission since October, 1946, and was appointed head of the classification office July, 1949. A brief biography of Dr. Luke appears on page 80 of this issue.

CHEMICAL FIRMS BID ON BUTADIENE PLANT

A joint bid for a Government-owned butadiene plant has been submitted by Merck & Co., Inc., and Climax Molybdenum Corp., according to a recent announcement. Although it cannot be completed until March, 1955, by Congressional arrangement, the joint venture if achieved will be operated by the companies on an equal basis. A discussion of the eight Government-owned butadiene plants appeared on page 64 of the August, 1953, issue of C.E.P.

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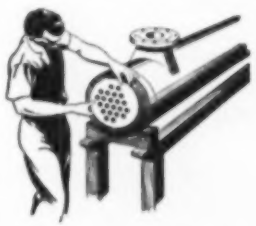

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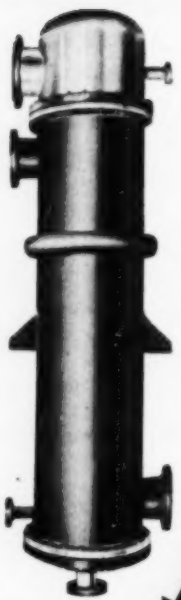

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DRAFTING OF ENGINEERS SCORED BY CHILTON

The need for effective utilization of engineers and scientists under the nation's selective service policy was brought to the attention of Congress by Thomas H. Chilton, chairman of the Engineering Manpower Commission of Engineers Joint Council, in a letter to Senator Alexander Wiley, which appeared in the *Congressional Record*. A similar letter from Dr. Chilton was published in *The New York Times* of July 11.

The letter to Senator Wiley said in part that the "implementation in Selective Service and in the Department of Defense of the concept of Universal Military Service . . . is threatening our entire graduate student program, taking many hundreds of engineers and scientists from the laboratories and installations that produce modern weapons and, in general, is enforcing a level of mediocrity of performance which is making it increasingly difficult for our technological manpower to make its highest contribution to the national well-being."

In rebuttal to an editorial in the *Times* referring to a shortage of physically qualified young men available for military service, Dr. Chilton wrote, "A cursory examination of the statistics will indicate that current induction requirements can be easily met without making any substantial inroad on the relatively small number of specialized personnel within the military age group whose intellectual attainments and technical training make them vitally necessary to the advancement of science and engineering."

TWO POLYETHYLENE UNITS FOR 1955

Erection of two new plants for the manufacture of polyethylene was announced recently, both units being scheduled for completion in 1955. A polyethylene unit for its Tuscola, Ill., plant is projected by National Petro-Chemicals Corp., and Koppers Co. will produce polyethylene plastic at its Port Arthur, Texas, site.

Koppers will produce polyethylene in pelletized form for sale to molders and extruders. National will supply its product in bulk shipment on a long-term contract basis.

National Petro-Chemicals engineers plan to divert low-pressure ethylene recycle streams from the polyethylene plant to the other ethylene-consuming processes at the plant which require a raw material lower in purity than that of the new unit. Facilities of the unit have been designed to permit rapid expansion in production to three and four times the original capacity.

EUROPEAN JOURNAL ON NUCLEAR ENERGY

A publication to be devoted to the "scientific, engineering, biological, and economic aspects of nuclear energy and its by-products" has been announced by the Pergamon Press, Ltd., of London. To be known as the *Journal of Nuclear Energy*, the periodical will be restricted mainly to papers on original work, although a few review articles may occasionally be included, as well as book reviews and conference reports. Papers may be in English, French, or German and each will be preceded by an abstract in English. The journal will be a quarterly with about 300 pages to a volume. Papers may be submitted to the journal at 242 Marylebone Road, London, N.W. 1, England.

AIR POLLUTION STUDIED IN CALIFORNIA

The first report of the Southern California Air Pollution Foundation, recently issued, suggests the type of activity that will be or is being undertaken by more and more industrial communities. Entitled "The Meteorology of the Los Angeles Basin," the report, according to its authors, Morris Neiburger and James Edinger, summarizes available information on the surface and upper air conditions in and around Los Angeles in an effort to trace the paths of air pollution.

The foundation is an independent nonprofit corporation devoted to studying and assisting in combating the pollution of air. Members of the board of trustees include representatives of industries in the region, as well as educators and businessmen. President and managing director is Lauren B. Hitchcock.

COMPLETE CENTENNIAL VOLUME AVAILABLE

The full texts of more than one hundred papers delivered at the Centennial of Engineering at Chicago in 1952 are contained in the "Centennial of Engineering: History and Proceedings of Symposia," published by the Centennial of Engineering, 1952, Inc. The papers are in the fields of the chemical industries, education and training, food, tools, transportation, mineral industries, structures and construction, communications, energy, health and human engineering, and urbanization.

Also included in the volume is the record of the observance: the theme and philosophy, the celebration activities, and the script of the stage presentation "Adam to Atom."

The book may be obtained at a cost of $10 from The American Society of Civil Engineers, 33 West 39 Street, New York 18, N. Y.

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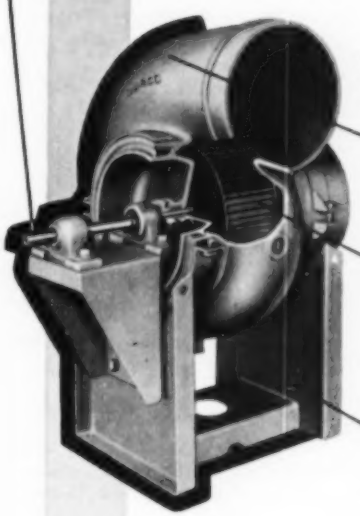
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FUTURE MEETINGS and Symposia of the Institute

MEETINGS **SYMPOSIA**

GLENWOOD SPRINGS, COLO., Hotel Colorado, Sept. 12-15, 1954.

Technical Program Chairman: Dr. Charles H. Prien, Head, Chem. Div., Denver Res. Inst., Univ. of Denver, Denver 10, Colo.

Agglomeration

CHAIRMAN: A. P. Weber, International Engineering, Inc., 15 Park Row, New York, N. Y.

Uranium Processing and Refining

CHAIRMAN: R. H. Long, Vitro Eng. Div., Vitro Corp., 120 Wall St., New York, N. Y.

Oil Shale and Shale Oil Processing

CHAIRMAN: W. I. R. Murphy, Pet. & Oil Shale Exp. Station, U. S. Bureau of Mines, P. O. Box 621, Laramie, Wyoming.

Deadline Past

ANNUAL—NEW YORK, N. Y., Statler Hotel, Dec. 12-15, 1954.

Technical Program Chairman: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Reaction Kinetics

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

Gas Absorption

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Solvent Extraction

CHAIRMAN: Dr. R. B. Beckmann, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

New Processes Utilizing Moving Beds

CHAIRMAN: N. Morash, Tit. Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Biochemical Engineering

CHAIRMAN: C. W. Weil, Chas. Pfizer & Co., 11 Bartlett St., Brooklyn 6, N. Y.

Deadline Past

LOUISVILLE, KY., Kentucky Hotel, March 20-23, 1955.

Technical Program Chairman: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Heat Transfer

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Deadline—November 20, 1954

HOUSTON, TEXAS, Shamrock Hotel, May 1-4, 1955.

Technical Program Chairman: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

MEETINGS **SYMPOSIA**

Flow of Fluids Through Porous Media

CHAIRMAN: H. Dayton Wilde, Mgr. Res. Div., Humble Oil & Ref. Co., Box 2180, Houston 1, Tex.

Azeotropic and Extractive Distillation

CHAIRMAN: Dr. D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

Deadline—January 1, 1955

LAKE PLACID, N. Y., Lake Placid Club, Sept. 25-28, 1955.

Technical Program Chairman: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Deadline—May 25, 1955

ANNUAL—DETROIT, MICH.—Statler Hotel, Nov. 27-30, 1955.

Technical Program Chairman: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Photochemical Processes

CHAIRMAN: Prof. J. J. Martin, Dept. Chem. Eng., Univ. of Michigan, Ann Arbor, Mich.

Deadline—July 27, 1955

LOS ANGELES, CALIF., Statler Hotel, Feb. 26-29, 1956.

Technical Program Chairman: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

Deadline—Oct. 26, 1955

ANNUAL—BOSTON, MASS., Hotel Statler, Dec. 9-12, 1956.

Technical Program Chairman: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Deadline—August 9, 1956

UNSCHEDULED

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Extraction of Hydrocarbons for Chemical Use from Pipe Line Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Bubble Mechanics

CHAIRMAN: Prof. R. C. Kintner, Dept. Chem. Eng., Ill. Inst. of Tech., 3300 Federal St., Chicago 16, Ill.

ONE-DAY ANNUAL SYMPOSIUM

New York Section, New York City—October 13, Hotel Statler

AUTHOR INFORMATION

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. S. L. Tyler, American Institute of Chemical Engineers, 120 East 41st Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended. one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 120 East 41st Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 120 East 41st St., New York, a copy of the A.I.Ch.E. Guide covers the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office. All manuscripts submitted to the A.I.Ch.E. Editor are automatically considered for C.E.P., the A.I.Ch.E. Journal, and the Symposium Series. Presentation at a meeting is no guarantee that manuscripts will be accepted.

Chairman, A.I.Ch.E. Program Committee
George Armistead, Jr., George Armistead & Co.,
1200 18th St., N.W., Washington, D. C.

Assistant Chairman
L. J. Coulthurst, Foster Wheeler Corp.
165 Broadway, New York 6, N. Y.

Glenwood Springs Meeting

(*Continued from page 35*)

coupled with Tuesday's trip to the Oil Shale Experimental Station of the Bureau of Mines at Rifle. In the project area oil shale is trucked from mines down a twisting, vertical shelf road to the plant, 2,200 feet below. There the oil shale is crushed, retorted, and refined. The tour will include the mine, the pilot plant, the new gas-combustion retort, and the thermal cracking and treating units.

The Monday afternoon symposium, Uranium Ore Processing, will be followed by a Wednesday trip to the Climax Uranium Company at Grand Junction where a modern mill recovers vanadium and uranium concentrates from ores mined in Colorado and Utah. Certain information is classified, but the visitors will see the first step in the production of material for atomic energy. This area is the center of activities for the Atomic Energy Commission and for many private companies prospecting, mining, and milling uranium ore. Persons taking this trip must prove United States citizenship.

Symposia on Agglomeration, The Role of Chemical Technology in Resources for the Future, and a general papers session round out the Technical Program.

For those staying through Thursday, a trip to the Climax Molybdenum Company near the Fremont Pass will cover the largest underground mine in North America, located at 11,300 feet altitude. It produces 27,000 tons of ore per day, which provides two thirds of the supply of molybdenum to the free world. The mill at Climax processes the ore and recovers concentrates. The trip itself is a sightseeing wonder.

Especially for the Ladies

A mid-morning coffee hour is planned for Monday, and it is rumored that the hotel will set up tables for bridge devotees. For Tuesday, a luncheon is planned at the Crystal River Lodge, a forty-room castle built in 1902 by the founder of the Colorado Fuel and Iron Company. It is now operated as a guest lodge, but the lavish decorations and furnishings are still in use. The ladies may inspect the main rooms of the mansion and its grounds.

Small

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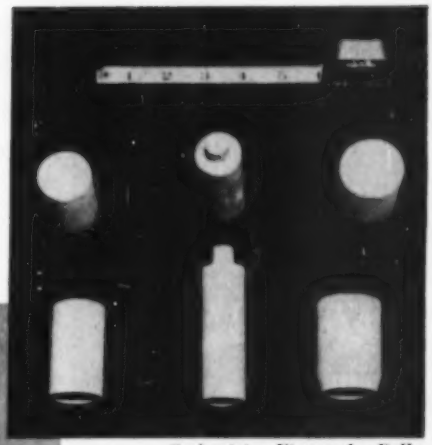

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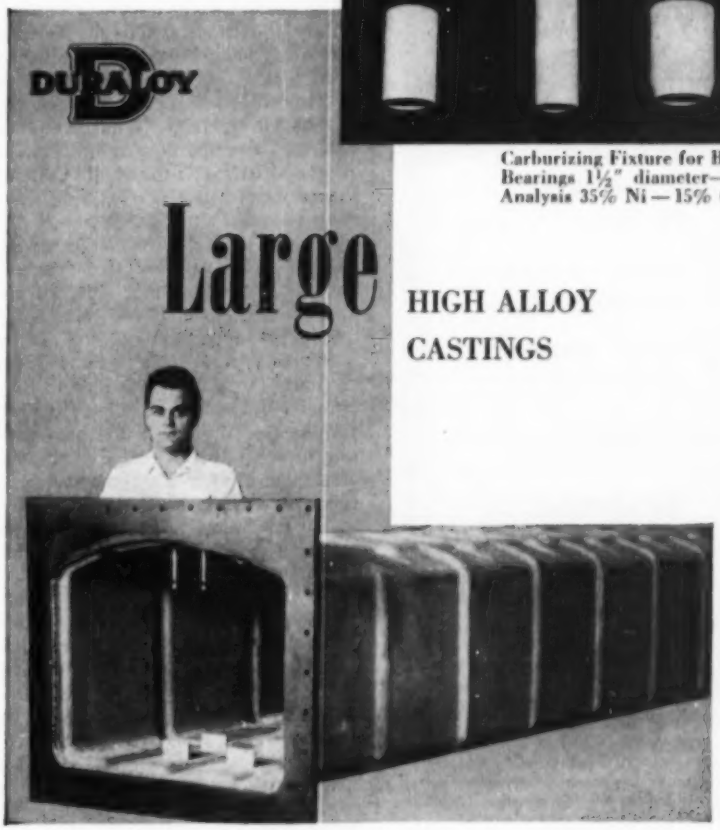

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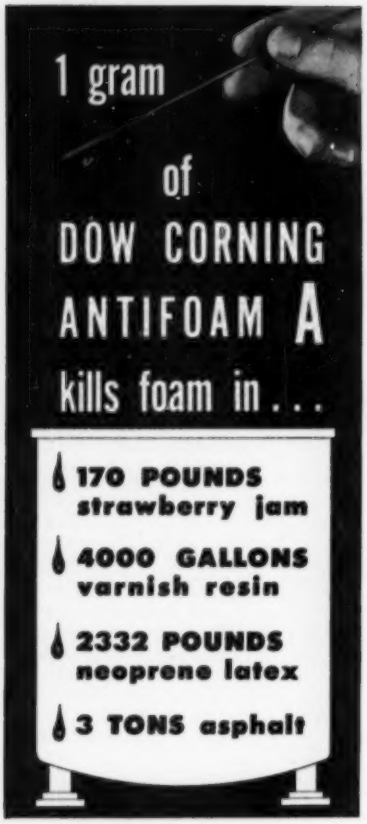

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PREVIEW

Glenwood Springs Meeting

Historically Speaking

Colorado's mountains—source of her wealth and secret of her lure—formed a forbidding barrier to early nineteenth century trail blazers. The ever present haze of the Rockies seemed a repelling force. Early explorers veered north through Cheyenne or south, bordering the Spanish territory. What is now the Glenwood Springs area at the junction of the Roaring Fork and Colorado Rivers seemed destined to remain forever a natural paradise.

Captain John C. Fremont came into western Colorado over the Tennessee Pass in 1845 in the first recorded visit by a white man, thirty-one years before Colorado's admission to the Union. Astor City was founded at the foot of Battle Mountain on the Eagle River by a fur trader in the employ of John Jacob Astor; however, this first settlement precipitated no great rush into the area. The Meeker Massacre was not to occur until 1879. N. C. Meeker, friend of Horace Greeley, was appointed agent for the Ute Reservation. He undertook to force a rapid change in the Utes from hunter and warrior to farmer. Chief Colorow, patron of the "healing waters" of Glenwood, led the Indians in their last great attempt to drive out the white man in the battle precipitated by the inflexible Meeker, which cost Meeker his life. Active settlement of the area began in the eighties after banishment of the Utes to their Reservation.

Industrially Speaking

Elsewhere in Colorado, as here, the magnet of the Rockies was the precious metals. The 1860's saw the establishment of the gold boom towns of Denver, Central City, Breckenridge, Gold Hill, and Georgetown. During the next decade, complicated political development included a battle with Texas forces attempting to occupy the territory for the Confederacy. During this time the extraction of gold and silver progressed at a rapid rate. Until 1890 a great part of the history of Colorado was written in the mining camps. After this, industrial conditions became confused and development seriously curtailed by strikes and lockouts in the mines. Martial law was necessary in 1894, 1896-7, and 1903-4. Questions of railways, franchises, union wage scales, and sheep and cattle interests entered into both the political and economic troubles of these years.

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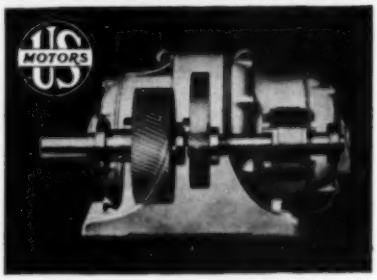

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PREVIEW

Glenwood Springs Meeting

The Colorado "labor wars," among the most important struggles between labor and capital, were certainly the most sensational of our history. A state board of arbitration was created in 1896, but its usefulness was impaired by a state attorney general's opinion (1901) that it could not enforce subpoenas, compel testimony, or enforce decisions. A law establishing an eight-hour day for underground and smelter workers (1899) was unanimously voided by the State Supreme Court. In 1902 the people amended the constitution and ordered the general assembly to re-enact a law for laborers in mines, smelters, and dangerous employments.

As for present-day industry, mining of the base metals—zinc, lead, and copper—is dominant, and gold and silver are recovered. Colorado ranks first in uranium, vanadium, and molybdenum. Uravan contains the largest uranium refining mill based on a new process for ores with high lime content. The Rocky Flats Plant near Denver also conducts uranium processing. At Climax is the second largest underground mine in the world. Colorado contains the largest bituminous coal reserves in the United States and the second largest sub-bituminous. The Rocky Mountain Region produced 109 million barrels of oil in 1951, and Denver has fast become an important oil town with more than 270 oil producers and ten refining companies.

United States reserves in shale oil dwarf known oil reserves. The government operates an experimental plant at Rifle, which was started by the Bureau of Mines in 1945 to develop a process for oil extraction from oil shale. Of the 2,600 square miles of oil shale in Colorado, a 1,000 square-mile area of the Piceance Creek basin has been very well defined and is estimated to contain 400 billion barrels of oil in a 500-ft. thick measure assaying 15 gallons per ton of shale. Colorado houses many smaller chemical industries: rubber, sugar refining, insecticides, cement, and paint.

Although early magnet of the Rockies was precious metal, agriculture followed closely and it has had a stabilizing influence on Colorado's economy ever since. Cattle and sheep provide the high dollar volume products, and sugar beets, hay, grains, and potatoes are important crops. Pulpwood production, which appears on the increase, poses an intriguing potential. The tourist business should not be overlooked in a discussion of Colorado industry.

Program of technical papers is on page 35.

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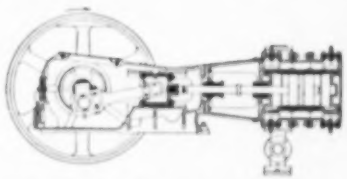

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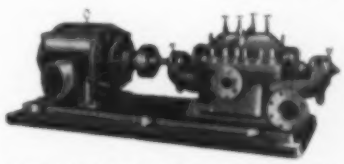

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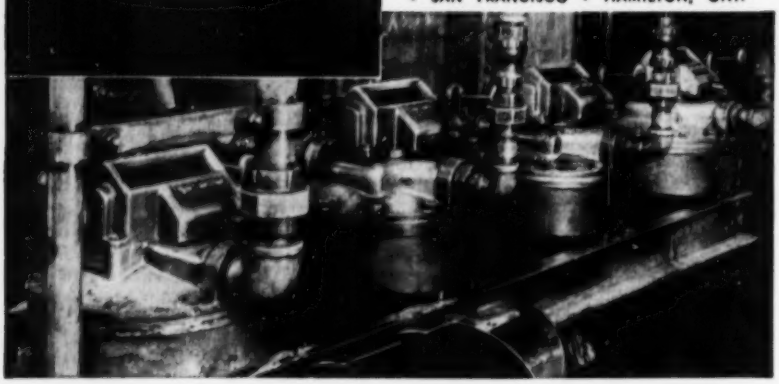

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PEOPLE

The appointment of **Carl F. Prutton** as vice-president and technical director, chemical divisions, Food Machinery & Chemical Corp., New York, was recently announced. Dr. Prutton graduated from Case Institute of Technology in 1920 and joined the staff of the school as an instructor. In 1936 he was appointed head of the department of chemistry and chemical engineering, a position he held until 1948. From 1942 to 1944, he was chief, process development branch, Office of Rubber Director and a consultant to the War Production Board, Dow Chemical Co., and the Lubrizol Corp. In 1948 Dr. Prutton joined Mathieson Chemical Corp. as director of research and a year later was appointed vice-president, director of operations, engineering and research, serving also as an officer and director of a number of Mathieson Chemical Corp. subsidiaries.

J. D. Booker is now technical specialist in technical service division, Baytown (Texas) refinery, Humble Oil & Refining Co. He received his B.S. degree in chemical engineering at the University of Texas in 1941 and joined the technical service division at Baytown immediately. As a technical specialist, his activities will be primarily in the fields of process designs of new installations and following their initial operations in the refinery.

Russell L. Jenkins is now associate director of inorganic chemical research in the chemical research department, research and engineering division, Monsanto Chemical Co. In 1927 he joined Swann Chemical Co. and went to Monsanto when it acquired Swann in 1935. He served successively as group leader, assistant director of research for the organic chemicals division, and in 1940 became director of research for the former phosphate division. When the inorganic chemicals division was organized in January of this year, Jenkins became director of science of the division. He has done extensive work in the fields of biphenyl derivatives, dielectrics, synthetic detergents and isocyanates. He has also worked on several classified projects for various government agencies.

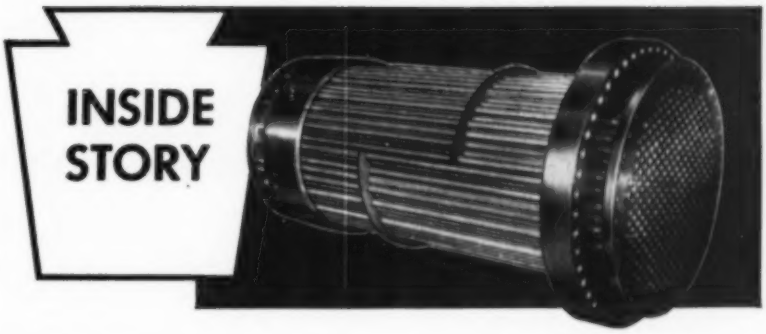
The appointment of **Edward J. Goett** as director of a newly-created commercial development department of Atlas Powder Co., Wilmington, Del., was recently announced. He received his B.S. degree from Fordham University in 1939 and his chemical engineering degree from Columbia University in 1942. For the past twelve years he has been employed by the Charles Pfizer Co. Starting in the research and development division of that company in 1942, he was appointed manager of sales development in 1948 and elected to the Board of Directors in 1952.

Blaine McKee, formerly an account executive with M. K. Mellott Co., Pittsburgh, public relations consultants, was recently appointed associate editor in charge of the Chicago office of American Metal Market, daily metals newspaper. For eight years a fellow at Mellon Institute of Industrial Research, he served for two years as associate editor of the Mellon Institute News. Earlier experience included technical assignments with Pittsburgh Plate Glass Co.; Timken Roller Bearing Co.; and Jones & Laughlin Steel Corp.

Thomas J. Wurth has recently joined the research and development department, explosives division, Olin Industries, Inc., East Alton, Ill. A graduate of Washington University with a B.S. degree, Wurth was a chemical engineer with the Mathieson Chemical Corp. for a year before joining Olin.

T. Ed Griffith, formerly senior engineer, gas utilization department at Houston is now supervisor of the gas and gasoline plant operations in the central division of Tide Water Associated Oil Co., Tulsa, Okla. After receiving his B.S. degree in chemical engineering from Oklahoma A.&M. in 1942, he served in the U. S. Army until 1946. He then returned to Oklahoma A.&M. to teach chemical engineering in the spring and summer of 1946. He joined Tide Water Associated in 1948 after obtaining his M.S. degree in chemical engineering at the University of Michigan. While in Houston, Mr. Griffith was a part-time instructor of gas engineering in the Petroleum Engineering Department of the University of Houston where he held the position of assistant professor.

(*More About People on page* 80)



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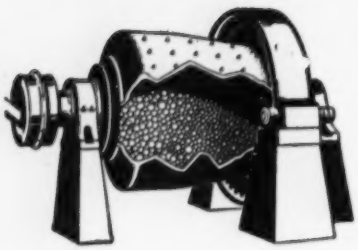

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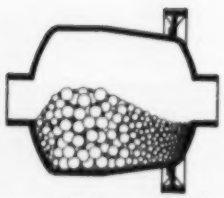
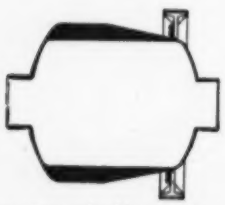


Correct ball segregation.



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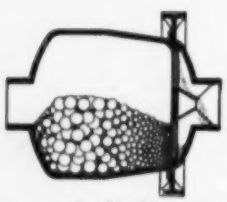

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NEW YORK ANNUAL SYMPOSIUM

Costs and new developments will be the subjects of the annual symposium of the New York Section of the A.I.Ch.E. to be held in the Hotel Statler, New York City, Oct. 13, 1954.

Stressing the practical, Roger Williams (Roger Williams Technical and Economic Service, Inc.) as chairman of the cost estimation session, A. H. Tenney (Carbide and Carbon) as chairman of the new developments in the chemical industries session, and L. J. Coulthurst (Foster Wheeler), chairman of the new developments in the petroleum industries session, have obtained speakers having major experience in their respective fields in industry.

It is expected that more than 500 chemical engineers and students will gather for this year's meeting. Last year's symposium, which concentrated on management, new materials of construction, and solids handling, was well attended by guests from all over the East.

COST ESTIMATION

A.M.

ESTIMATING MAINTENANCE COSTS FOR NEW PLANTS, Roy Ganz, Diamond Alkali Co.

DEPRECIATION AND AMORTIZATION, C. R. Schwartz, Du Pont Co.

COMPARISON OF CHEMICAL AND PETROLEUM ACCOUNTING IN ANALYSIS OF NEW PLANT ECONOMICS, Robert Wiegand, Sinclair Chemicals, Inc.

P.M.

COSTS OF LOW TEMPERATURE PROCESSING, Edward Donley, Air Products, Inc.

COSTS OF PRESSURE EQUIPMENT, Val Weiler, A. O. Smith Manufacturing Co.

COSTS OF CHEMICAL PLANT AUXILIARIES, Carl Bauman, Chemical Construction Co.

NEW DEVELOPMENTS IN THE CHEMICAL AND PETROLEUM INDUSTRIES

A.M.

TEXTILE FIBERS, C. A. Setterstrom, Carbide and Carbon Chemicals Co.

ANTIBIOTICS, Jasper Kane, Charles Pfizer.

SURFACTANTS AND DETERGENTS, T. H. Vaughn, Colgate Palmolive Peet.

P.M.

HOUDRY DEHYDROGENATION PROCESS, G. F. Hornaday, Houdry Process Corp.

CATALYTIC DESULFURIZATION OF PETROLEUM DISTILLATES, L. W. Zahnstecher, Foster Wheeler Corp.

FLUID COKING, Frank Barr, Standard Oil Development Co.

—A. L. REGNIER

Rochester. At the final meeting of the 1953-54 season the new officers were presented. They are:

Chairman.....W. F. Kaiser
Vice-Chairman.....J. Y. Oldshue
Secretary.....R. R. Kraybill
Treasurer.....W. H. Eilinger
Board of Directors, G. Broughton, A. Ackoff, and retiring chairman I. Siller.

These men will serve for the 1954-55 season.

The evening's entertainment was provided by George Bailey, a variety entertainer, who specializes in demonstrations of his fabulous memory. He also presented some feats of magic and played musical glasses.

—W. H. EILINGER

New Jersey. E. R. Rowley, president, Titanium Metals Corporation of America, a jointly owned subsidiary of the National Lead Co. and Allegheny Ludlum Steel Corp., will address this Section on Sept. 14, 1954, at the Clinton Avenue School, Plainfield, N. J. His topic will be "Titanium—Its Past, Present and Future."

E. R. ROWLEY

In 1933 Mr. Rowley joined the mechanical engineering department of the National Lead Co. in Chicago and later he was transferred to its production department in New York, where he served as assistant to the production manager until his appointment in 1942 as plant manager of the Magnesium Reduction Co., Luckey, Ohio. From there he went to Chicago in 1945 as production manager of National Lead Co.'s Chicago plants. He became production manager of National Lead Co. in New York and subsequently vice-president and general manager of the National Lead Co. of Ohio, operator of the Atomic Energy Commission's Feed Materials

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Production Center at Fernald, Ohio. He became president and a director of Titanium Metals Corporation of America in September, 1953.

Officers for the New Jersey Section for the year 1954-55 are:

Chairman — Norman Morash, National Lead Co.
Chairman-Elect—D. W. Oakley, Metal & Thermit Corp.
Recording Secretary—D. D. MacLaren, Standard Oil Development Co.
Corresponding Secretary—George J. Marlowe, American Cyanamid Co.
Treasurer—Joseph Joffe, Newark College of Engineering
Executive Committee—E. F. Jennings, Jr., Past Section Chairman, Hercules Powder Co.; Wm. E. Catterall, Standard Oil Development Co.; T. S. Leary, American Cyanamid Co.; Wm. C. Streib, Johns-Manville Corp.

Committee chairmen for the New Jersey Section are:

Program—C. R. VanderLinden, Johns-Manville Corp.
Meeting Place—R. W. Davis, General Aniline & Film Corp.
Hospitality—John Axelson, Johns-Manville Corp.
Publicity—Robert Bechtel, Hercules Powder Co.
Speakers—Donald M. Calkins, Merck & Co., Inc.
Symposium — Charles L. Kroll,, E. R. Squibb & Sons.
Student Guidance — Ralph Cohen, Hoffmann-LaRoche, Inc.
Membership—Lewis C. Marino, Benzol Products Co., Roger Walwark, Vice-Chairman, National Lead Co.
Lecture Series—C. M. Vanderwaart, American Cyanamid Co.
Audit—William T. Harbin, Kolker Chem.
Survey—D. W. Oakley, Metal and Thermit Corp.

R. J. BECHTEL

MINERS SCARCE IN ENGINEERING CENSUS

The downward trend in the number of mining and metallurgical engineers has not been checked by the gradual increase in total engineering student enrollment, according to the *Engineering and Scientific Manpower Newsletter*. Of the engineering students in the class of 1953, 3.8% were in mining and metallurgy, and in the classes of 1954, 1955, and 1956 the percentages have dropped to 3.1. 2.3, and 1.6 respectively. In fact, only 5% of the 519,000 professional engineers reported in the 1950 census were in mining or metallurgical work.

FORMER BRITISH INSTITUTE HEAD DIES

The death of Hugh Griffiths, president of the Institution of Chemical Engineers in 1945 and 1946, was reported recently. Mr. Griffiths was on the board of British Carbo-Union, Ltd., and did much of his work in high vacuum and continuous crystallization.

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PEOPLE

(Continued from page 77)

LUKE DIRECTS A.E.C. OFFICE OF CLASSIFICATION

The new incoming director of the Office of Classification, Atomic Energy Commission, is Charles D. Luke, who served as consultant to A.E.C. from 1950-52 on source and fissionable materials accountability surveys, and has been professor and chairman of the department of chemical engineering at Syracuse University since 1940. In his new post he succeeds James G. Beckerley, who is resigning as of Aug. 31.

Following a period of about a year with the New York Ordnance Works as technical officer on design, construction, and initial operation of ammonium picrate plant, Dr. Luke took over the job of technical officer on fluorine and hydrocarbon research, uranium chemistry, and pilot plant development with the Manhattan Engineer District. Later he was operations officer for the gaseous diffusion plant at Oak Ridge, Tenn.

Back in 1932 with degrees from Iowa State University and Massachusetts Institute of Technology, Dr. Luke became a research assistant at M.I.T. and his subsequent experience covered a period with the Standard Oil Company of Louisiana, Baton Rouge, as process engineer, de Florez Engineering Co., New York, as consultant for various oil companies in refinery surveys, cost analyses, and then in 1937 Syracuse University successively as assistant, associate, then professor of chemical engineering and department head.

Leonard Limon is now manager of the industrial boiler feed department, Graver Water Conditioning Co., New York. He joined the company in 1949 to take charge of the estimating department. More recently he has been sales engineering manager.

Alfred B. Babcock, Jr., became chief project engineer with the chemical division of the Borden Co., New York, effective July 1. He was formerly associated with the New York Operations Office of the Atomic Energy Commission.

Bjorksten Research Laboratories, Inc., recently announced the appointment of **George D. Creelman** as technical service director, with offices in Cleveland, Ohio, to act in a liaison capacity between the technical staff at Madison, Wis., and clients sponsoring research programs with the organization. Mr. Creelman was formerly research coordinator for the M. A. Hanna Co. in Cleveland.

Mott Souders, Jr., scientist, Shell Development Co., Emeryville, Calif., was recently granted an honorary doctor of science degree by his alma mater, Montana State College. Among Dr. Souders' scientific achievements since joining Shell in Wilmington, Calif., seventeen years ago are some sixty technical papers and twenty patents. In 1949 he received the professional progress award of the A.I.Ch.E., and in 1953 he was given a citation for outstanding accomplishments at the centennial of engineering at the University of Michigan. Beginning his Shell career as an engineer at Wilmington, Dr. Souders transferred to the San Francisco engineering office in 1940, was appointed an associate director of the company's development division in 1950, and moved to the Emeryville Research Center with his division two months later.

David S. Weddell was recently named European technical representative for Monsanto Chemical Co., St. Louis, Mo. Dr. Weddell, who has been assistant director of the development department, will take over his European duties later this year. He joined the company in 1941 after receiving a Sc.D. degree in chemical engineering from Massachusetts Institute of Technology. He had been graduated from Pennsylvania State College in 1938 with a B.S. degree in the same field. In addition to working for the general development department, he has served the central research department, the phosphate division research department, and the development department, Western division.

Angelo V. Graci, Jr., one of the inventors of the filtration-extraction method of solvent extraction, formerly with the Southern Regional Research Laboratory, is now associated as a project engineer with Wurster & Sanger, Inc., Chicago, Ill.

(*More about People on page* 83)

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Broad experience in design and operation of intermediate-scale fine organic chemical manufacturing facilities. Southwestern location in medium-sized community.

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Bartlesville, Oklahoma

ONE CHEMICAL ENGINEER for process engineering work. Should have three to five years' practical experience in organic chemicals and organic chlorinations and should be capable of both field and desk studies for process, efficiency, and equipment improvements.

ONE CHEMICAL ENGINEER for process engineering work. Must have a chemical engineering degree; however, previous experience is not required.

Write fully giving technical background, experience, personal history and initial salary expectation. All applications will be held in strictest confidence.

Excellent opportunities for men with initiative and ability. Liberal company benefits.

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Wanted for process and equipment evaluation and development; trouble shooting.

We are an expanding division of a medium-sized company, engaged in pilot-scale production of **Solid Propellants.**

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Send reply stating full background and desired salary to Box 23-8.

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CHEMICAL OR REFINERY ENGINEERS—For permanent staff positions with integrated oil company which manufactures all important petroleum products. Duties involve advisory work on operations, preparation of operating programs, processes and economic evaluations. Knowledge of gasoline and lube manufacture desirable. Excellent future for engineers with one or more years' experience. Salaries commensurate with ability and experience. List training, experience and personal data in first letter. Replies confidential. Write Box 6-8, Chemical Engineering Progress.

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B.S. or M.S. in chemical engineering, plus six to twelve years' diversified chemical industry experience required in economic evaluation, cost estimating, process plant design and plant operation. We are looking for a man who combines initiative, imagination, and drive with speed, thoroughness, and accuracy in handling a variety of assignments. Compatibility and the ability to work well with people also essential. Salary is open, opportunity excellent, and location (25 miles from Los Angeles) one of the best in Southern California. Please send a complete résumé and recent photo to

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Your inquiry will be held in strictest confidence.

SALES ENGINEER — Must have technical ability, degree in chemical engineering, and knowledge of filtration based, to a large extent, on actual experience in the chemical processing field. Desire a man between 30 and 40, who is sincerely interested in permanent career in sales engineering. Attractive base salary plus commission. Location —New England States. Please send complete résumé to Box 2-8.

PROCESS ENGINEERS—Permanent positions available requiring a Ch.E. degree and three or more years' experience in process design and development of oil refinery or chemical plant units. These are excellent opportunities to join an organization known throughout the world for accomplishments in these fields; located on the East Coast. Traveling and moving expenses paid. Please submit complete résumé and state initial salary desired. Box No. 423, Room 1201, 230 West 41 Street, New York 36, N. Y.

CHEMICAL ENGINEER—Born and reared in South, 25-27 years old, married. One to three years' experience in large company and tired of being lost in the bigness. Must have love of all phases of engineering and willingness to work long and hard for good opportunity with small, growing, sound chemical manufacturing company located in small town in Georgia. Production, engineering, development and supervisory responsibilities. Send résumé and salary required. Box 4-8.

ENGINEERS AND CHEMISTS—With oil refining experience for positions in sales and technical service to the petroleum industry. Familiarity with fluid catalytic cracking desirable. Salary dependent upon qualifications. Please reply to Box 22-8 stating age, experience, and salary requirements.

CHEMICAL ENGINEERS

Immediate vacancies for chemical engineers to do process design and development work at the pilot plant level in Minneapolis. 22-30 years old, B.S. degree in chemical engineering. Experience in industrial chemical research, chemical pilot plant or chemical production preferred. Include complete résumé of training and experience in letter.

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A.I.Ch.E. Members

CHEMICAL ENGINEER—B.S. 1941. Thirteen years' experience in economic evaluation, process design, and operation of petrochemical and nitrogenous fertilizer plants. Desire position in small organization with incentive program. Present salary $10,000 annually. Box 3-8.

CHEMICAL ENGINEER—Age 29, M.S.Ch.E. 1½ years' technical service to production in large food company. Six years' pharmaceutical pilot plant and production. Supervisory experience. Desire position in production, technical service, or sales. Box 7-8.

NUCLEAR-CHEMICAL EXECUTIVE — Seek managerial or liaison connection with company interested in atomic energy possibilities. Broad and diversified background all phases of atomic energy. Experience in research, development, engineering and sales in instrumentation, textiles, plastics, metallurgy, nuclear industrial participation. M.S. in chemical engineering. Box 8-8.

CHEMICAL ENGINEER—B.S.Ch.E. Registered chemical and civil engineer. Family. Seven years of excellent industrial experience with responsible positions in engineering and production trouble shooting. Desire position with chemical or consulting firm on West Coast. Box 9-8.

DIRECTIONS FOR USE OF CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 15c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section of Chemical Engineering Progress agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $15 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

CHEMICAL ENGINEER—B.Ch.E. Age 29, married. Graduate work in organic chemistry. Four years' experience in polymerization, synthetic resins, and foam rubber development. Desire position with growth potential. Publications and excellent references. No geographical limitations. Box 10-8.

CHEMICAL ENGINEER—Age 26, family. B.S.Ch.E. Graduate work in mathematics, statistics, and chemical engineering. Draft exempt. Five years' experience in research and development and technical sales. Desire responsible position in research and development field. Will relocate. Box 11-8.

DESIGN-DEVELOPMENT GROUP LEADER—M.Ch.E. Ten years' experience. Seeking responsibility and opportunity for hard, productive work with pilot plant or design group. Position should call for personal initiative, technical skill, independent thinking, administrative responsibility. Box 12-8.

CHEMICAL ENGINEER—B.Ch.E. Age 34, married, family. Five years' development and process engineering in food industry. Four years as sales manager in instrument industry. Desire responsible position, administrative engineering capacity. Location—northern New Jersey. Available with notice. Box 13-8.

CHEMICAL ENGINEER—B.Ch.E. 1952. Two years' experience in process design. M.Ch.E. partially completed at night. Good scholastic record. Age 23, married, draft exempt. Desire responsible position in design or development. Box 14-8.

CHEMICAL ENGINEER—B.Ch.E. 1951. Married, veteran. 1½ years' process piping design. Presently employed in production section of pyrotechnic and armament plant. Desire challenging position with a future in metropolitan New York. Box 15-8.

CHEMICAL ENGINEER—B.Ch.E. 1951. Age 26, veteran, married. Graduate work toward M.Ch.E. Three years' experience includes pilot plant design and operation, process engineering design, economic evaluations. A.E.C. clearance. Desire position in metropolitan New York area. Box 16-8.

POSITION IN WESTERN GERMANY with American company desired by chemical engineer with five years' experience in process design of synthetic fuel and petroleum refinery units. American citizen. Age 30. Speak German. Master's degree. Available September. Box 17-8.

CHEMICAL ENGINEER—Fifteen years' experience as general engineer, technical editor, and development engineer. Want position in process design or plant engineering. Considerable experience in liquid oxygen plant design and operation. Now located in New Jersey. Box 18-8.

CHEMICAL ENGINEER—Desire transfer to engineering or production job in New England. S.B. 1939. Varied experience in process design, plant operation, and general engineering. Available for interview in N.Y.C. or elsewhere by appointment. Box 19-8.

CHEMICAL ENGINEER—M.Ch.E. Age 31, family. Six years' experience in plant start-ups, trouble shooting, and process engineering. Seeking responsible position in production or allied fields. Available with reasonable notice. Present annual salary $7,000. Box 24-8.

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TECHNICAL REPRESENTATIVE seeking additional lines. Covering Texas and Louisiana Gulf Coast chemical plants, petroleum refineries, gasoline plants, paper mills, and plant constructors. Calling on purchasing, engineering, maintenance, and inspection departments. Presently selling custom-fabricated steel processing equipment. Wish to represent additional manufacturers of allied lines such as pumps, valves, filters, carbon products, ceramics, feeders, flexible joints, grinding mills, strainers, tower packing, extractors, finned-tube air coolers, etc. Write Box 20-8, Chemical Engineering Progress.

CANADIAN CHEMICAL ENGINEER—M.Sc. Age 30, married. Three years' experience. Desire position northern or northeastern U. S. A. offering good future. Box 21-8.

PEOPLE

(*Continued from page* 81)

R. Marvin Garrett recently resigned as sales manager for Silver Plastic Co. to assume the duties of general manager of Chem-Nickel Co., South Gate, Calif. Prior to his work as sales manager and partner with Silver Plastic Co., he was associated with Taylor Instrument Co. and Rohm & Haas Co. His graduate work in business administration was done at the University of Chicago, Ohio State University, and University of California.

Ralph A. Morgen, formerly program director for engineering of the National Science Foundation in Washington, D. C., has recently become director of research, Purdue Research Foundation. A graduate of the University of California, he received his B.S. degree in 1923 and his doctorate two years later. His experience has included two years with Western Electric Co., Chicago, as research engineer; four years as director of research and development for the cleaners equipment division of Black, Sivalls and Bryson Mfg. Co., Kansas City, Mo.; six years as a consulting chemical engineer, and fourteen years as professor of chemical engineering at the University of Florida, the last five years of that time spent as director of the Engineering and Industrial Experiment Station. He resigned that position in 1952 to accept the position of program director of engineering of the National Science Foundation.

Eugene M. McEachin, formerly of Du Pont's Sabine River Works, Orange, Tex., has been promoted to superintendent of the general products group, technical section, at the company's Belle Works. Shortly after graduation in 1948 from the Alabama Polytechnical Institute, he joined Du Pont as a member of the Sabine plant's technical section, subsequently serving there as an instructor in a training school for operators, and as an engineer and group leader in the nylon group of the technical section. He became assistant superintendent of Sabine's nylon plant development group in January, 1953, and held this post until his transfer to Belle.

Frank E. deVry is now assistant manager, Missouri Ammonia Works, Hercules Powder Co., Louisiana, Mo. He has been acid department supervisor since April, 1951, at the California plant of Hercules. Joining the company in June, 1942, at the government-owned Radford Ordnance Works, Radford, Va., he left there after World War II to serve as an engineer at Hercules' Naval Stores plant, Hattiesburg, Miss.

(*Continued on page* 84)

Problem

To produce more ammonia without excessive expansion of existing facilities.

Solution

GIRDLER helped solve this problem by developing two highly active catalysts, G-19 and G-3. Without sacrificing quality or enlarging the gas plant, the use of these two GIRDLER Catalysts on synthesis gas production resulted in:

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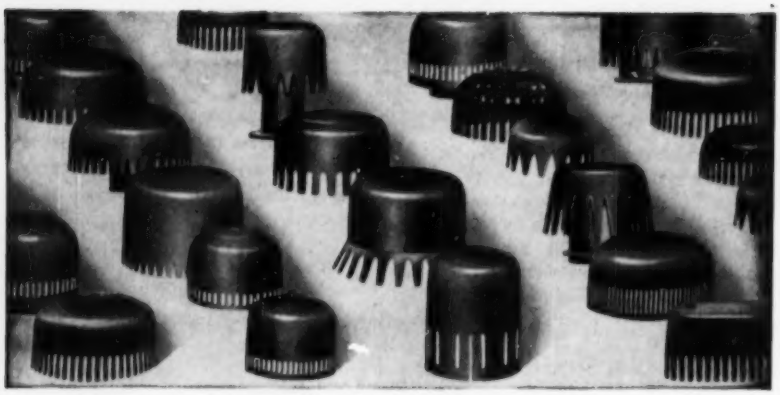

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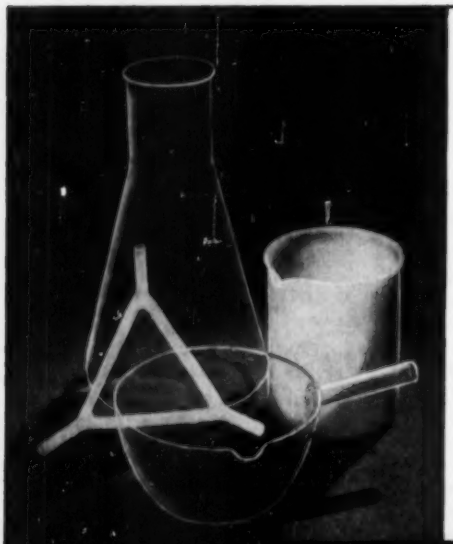

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Bulletin No. 18 with specifications and prices, sent upon request.

John J. McKetta, Jr., has recently resigned as editorial director of the *Petroleum Refiner* to return to the University of Texas as professor of chemical engineering. Dr. McKetta had been a member of the chemical engineering staff at the university from 1946 until 1952 when he resigned to go with *Petroleum Refiner*. He will return as graduate professor and will re-establish his research program in phase equilibria in hydrocarbon systems. In 1952 he was awarded a bronze plaque for the best paper published by a member of South Texas Section A.I.Ch.E.

Clifford F. Rassweiler, vice-chairman of the board of directors and vice-president for research and development of Johns Manville Corp., New York, is the newly elected honorary chairman of the American Section, Society of Chemical Industry, for the year 1954-55. Dr. Rassweiler went to Johns-Manville in 1941 as director of research and development after seventeen years with the DuPont Research organization. From the University of Illinois, where he received his Ph.D. in 1924, he went to the Experimental Station of the DuPont Co., in Wilmington, Del., and later to Philadelphia to help organize the new central technical laboratory of the DuPont Paint and Varnish Division, designed to apply scientific research methods to the paint industry. The University of Denver conferred the honorary degree of Doctor of Science upon Dr. Rassweiler for his work in industrial research.

Necrology

Chemical Engineering Progress recently heard of the death of Edward Strunk and Francis E. Murphy.

Mr. Strunk was chief process and design engineer with the Phillips Petroleum Co., Sweeny, Tex. He graduated from Oklahoma University with a B.S. in chemical engineering. He was associated with Phillips since 1940.

Francis E. Murphy was production supervisor of the Pennsylvania Salt Mfg. Co. His professional career covered an association of eight years with the General Chemical Co., and with the Pennsylvania Salt for ten years. He was a graduate of St. Joseph's College with a B.S. in chemistry.

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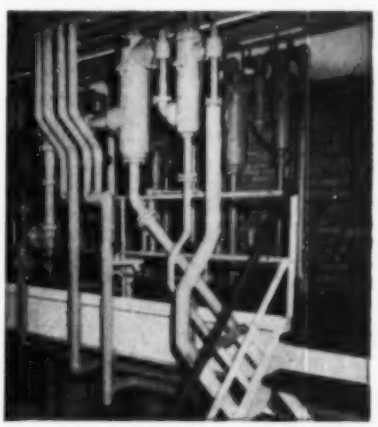

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This steady, dependable vacuum is contributing to the improved health of our population by helping to supply purer and more potent vitamins, antibiotics and other pharmaceutical products. C-R also supplies Jet Mixers, Jet Heaters, Jet Absorbers, Jet Scrubbers, Jet Pumps, Jet Condensers and Barometric Condensers.

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A.I.Ch.E. News And Notes

Equipment Testing Procedures Committee had its progress reviewed recently before Council by W. T. Dixon, its liaison member.

Agitator Test Subcommittee has a preliminary draft . . . distillation code has been redrafted . . . code on dryers is in its final stages . . . a second code for heat exchangers is being redrafted . . . & the formation of a new subcommittee on Instruments & Measurements is being considered.

Other revisions & codes in various stages of preparation concern absorbers, evaporators, & pumps.

Committee is well staffed with members from equipment manufacturing concerns & other divisions of the industry . . . code on heat exchangers already published is available from the Secretary's office.

This committee was started in 1948 to formulate and promulgate recommended standard procedures for testing performance characteristics of chemical engineering equipment.

W. R. Marshall, Jr., of the University of Wisconsin is chairman this year.

An important new Institute procedure was approved by Council at Ann Arbor when it legislated permission for editors of the A.I.Ch.E. magazines to appoint Advisory Boards to magazines . . . step will enable editors to select advisers in position to give a maximum of advice & cooperation.

Institute is in new headquarters . . . & move brings relief from badly overcrowded offices.

We urge all members when in New York City to stop in to pay us a visit . . . new address is 25 West 45 Street . . . new telephone number is COlumbus 5-7330.

Before move was made headquarters occupied an average of 87 sq. ft. a person including reception, storage, etc. New space will increase to 132 sq. ft. an employee, which is about average for offices.

Housing is still a major problem for all five engineering societies . . . newest development is the creation of a task force working under the sponsorship of United Engineering Trustees but ultimately to report to & cooperate with the committee of the presidents of the engineering societies. A task-force project is to study all the interlocking problems involved in new space . . . or a move to a new city.

New study will go into such details as cost of moving staff & families to various cities . . . cost of rehabilitating present engineering headquarters . . . cost of construction in various cities . . . supply of manpower for engineering staffs . . . evaluation of functions which cannot be carried on outside of New York . . . etc. . . .

Cities under study are Chicago, Philadelphia, Pittsburgh, & New York . . . task force is under direction of Carey of the Civil Engineers, Hibshman of the Electricals as vice-chairman, us as Institute representative, Apol of the Miners, and Zecca of the Civils, who is also secretary of the committee.

New Directory of the A.I.Ch.E., held up to await outcome of balloting on the constitutional amendments, will be out in August . . . most members have already sent in requests (with dues last year) for their copies . . . others may do so at any time.

A revision of standard symbols & nomenclature in chemical engineering is about ready. An Institute committee under the chairmanship of Mott Souders of Shell Development Co. has been working for a number of years on revision of 1946 standard.

Chemical field still prefers to use periods after abbreviations, a practice at variance with A.S.A. standard . . . however A.S.A. has agreed to call attention to it in its own standard on abbreviations.

Souders' committee is another example of the careful, patient work done by A.I.Ch.E. committees.

Original standard issued in 1946 had not been out very long when work was under way on revision . . . & so it will be with this.

A.I.Ch.E. members will soon be quizzed by the Program Committee on advisability of holding a Bermuda meeting . . . exploratory work is now being headed by Gene Smoley, & one of the first plans is to tap the opinion of the members on whether they will support such a meeting in 1956.

F.J.V.A.

In problems of chemical processing —

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Whether your particular chemical process problem is of broad or limited scope, it will be worthwhile to review it in terms of one or more of these Vulcan services:

- Economic and technical surveys
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- Process development
- Pilot plant studies
- Process and plant design
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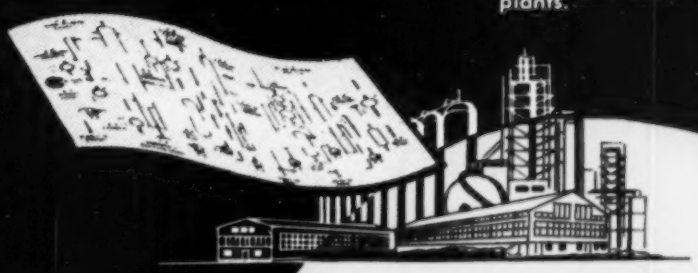
- Initial operation services

. . . or the full integration of all these services in the design and building of complete process units or plants.



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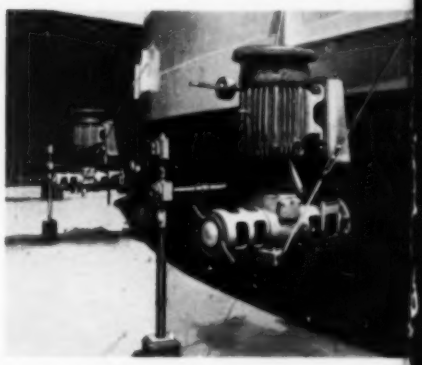

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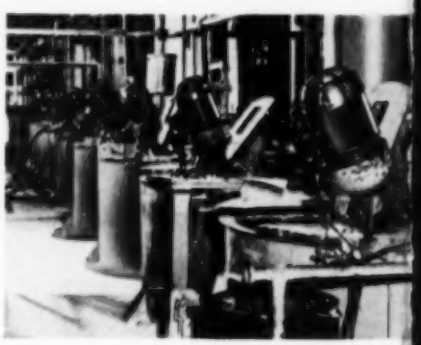

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